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RECENT TYPES

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DYNAMO-ELECTRIC MACHINERY

A COMPLETE GUIDE FOR THE ELECTRICIAN, ENGINEER,
STUDENT AND PROFESSOR

BEING A VALUABLE HISTORY OF THE EXTRAORDINARY ADVANCE IN THE BUILDING
OF AMERICAN DYNAMO MACHINES AND THEIR APPLICATION

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shown in Color, including Tables of exceptional value*

James

BY

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Joint inventor of the Thomson-Houston system of electric lighting, author of "Houston's
Dictionary of Electrical Words, Terms and Phrases," and other works

AND

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PREFACE.

ALTHOUGH many books have been written on the subject of dynamo-electric machinery, yet, so far as the authors are aware, none have yet appeared that have been devoted entirely to American types of machines ; or, at least, none in which these have been treated from an entirely practical standpoint, with copious illustrations, enabling the reader to form precise ideas concerning the exact appearance, function, and behavior of American machines.

It is in view of this fact that the authors have been persuaded to prepare, as one of the volumes of "The International Electrical Library," the volume entitled "Recent Types of Dynamo-Electric Machinery."

It has not been the object of the authors to prepare a treatise concerning the principles of dynamo-electric machinery, or the theory of its operation, but rather a descriptive treatise of the various types of machines made by different manufacturers, with their sizes, data, functions, and capabilities. It is often of great value to the student, the manufacturer, and the prospective purchaser or employer of machinery, to be acquainted with the most recent types of dynamo-electric machinery that are actually constructed and on sale in this country by the different makers. By these means a comprehensive view of the existing art relating to the construction and use of dynamo-electric machines is obtained which could not be reached in any other way.

In describing the various machines, attention has particularly been given to the practical rather than to the theoretical side of the subject. For this reason the book is readily capable of comprehension by the entire community, and is not limited, as many books on dynamo-electric machinery necessarily are, to those skilled in electro-technics. It will, however, the authors believe, be found of especial interest to the manufacturers, purchasers, designers, users, and students of electric apparatus.

The authors desire to acknowledge the courtesy and aid which they have received from the various manufacturers in preparing the material for publication.

PHILADELPHIA *December*, 1897.

RECENT TYPES OF
DYNAMO-ELECTRIC MACHINERY,

BY

EDWIN J. HOUSTON, PH. D., AND A. E. KENNELLY, Sc. D.

CHAPTER I.

INTRODUCTORY.

THE closing years of the 19th century will undoubtedly be identified with a very rapid advance in dynamo-electric machinery. Prior to 1880, only a very few dynamo-electric machines were in commercial service, and these were exclusively employed in operating arc lamps.

During the last decade rapid strides have been made both in the number and size of dynamo-electric machines. Thus, in 1890, the largest dynamo-electric machine constructed in the United States was of about 500 horse-power, while at the World's Columbian Fair, in 1893, a 2,000 horse-power dynamo was exhibited, which was justly regarded as of colossal proportions. And yet, only three years later, a 5,000 horse-power dynamo was constructed and set to work at Niagara Falls. Although this is by no means the limit to the possible power of the dynamo-electric machine, yet it is the greatest power which has, up to the present time, been placed in a single dynamo in actual use.

Coincident with this development in size, there has also been a development in mechanical and electrical qualities. The dynamo-electric machines of past years were often mechanically frail. The wires carried upon the revolving armatures were liable to accidental derangement. The dynamo-electric machine of the modern type is not only much stronger than its predecessor in mechanical qualities, in self-lubricating capability, and in durability, but is also more efficient electrically. Large dynamos like that shown in Fig. 178, when free of journal friction, claim an efficiency of 97 per cent; or, deliver as electrical power, at full load, 97 per cent of the power expended in driving them, thus losing only about 3 per cent in the process.

Development in dynamo-electric machinery has followed definite and well recognized lines. While it is impossible to predict what the dynamo-electric machine will be in the middle of the next century, yet we may be satisfied that its development will, probably, go forward from the present time along the direction which it has followed in the past five years.

It has only been during the last ten years that special types of dynamos and motors have been designed for special kinds of work. This is especially true in the application of motors. Prior to this time, motors were practically applied alike to all classes of work, independently of the particular service they were required to perform. At the present time, both dynamos and motors are constructed of types suited for each particular class of work. Thus, the type of dynamo suitable for supplying current to an office building, differs from the type suitable for supplying power to a long distance. The travelling motor, such as applied to a crane, or a street-car, differs from the stationary motor intended to operate a line of shafting.

All dynamo-electric machines may be divided into two classes; namely, *generators;* or those which generate electricity at the expense of mechanical power, and *motors;* or those which develop motion or mechanical power, when supplied with a suitable electric current. Many generators may be used as motors; i. e., when an electric current is sent through them, they rotate and develop mechanical power. Similarly, many motors may be used as generators; i. e., when rotated by mechanical power, they generate an electric current.

There are, however, even in those types of dynamo-electric machines which are immediately capable of interchangeable use, sufficient differences in detail to make it advisable to describe generators separately from motors. Moreover, in certain types of machines the difference between commercial forms of generators and motors is so marked that a separate description of each is necessary.

CHAPTER II.

DIRECT-DRIVEN CONTINUOUS-CURRENT GENERATORS FOR ISOLATED PLANTS.

GENERATORS designed for isolated service vary both with the character and the size of the plant required. Some isolated plants, as, for example, those which supply a large hotel, office building, or city block, are almost indistinguishable from central-station plants, except in the fact that the district they supply is close to the dynamos, so that the system of supply mains is comparatively short and simple.

Large isolated-plant dynamos are almost always *directly connected* to their driving engines; that is to say, the dynamos are mounted directly on the engine shafts, without the intervention of gearing or belting. The advantage of this arrangement is that all belting is dispensed with. This not only eliminates the wear and tear of belting, but also the possibility of accident from a moving or broken belt, and, moreover, economizes considerably in floor space, a desideratum in many cases of no little importance. On the other hand, the first cost of a direct-driven generator, of given power, is generally greater than the first cost of a belt-driven generator, for the reason that the latter is usually run at a greater number of revolutions per minute than an engine can be conveniently and economically made to give. Other things being equal, the faster a dynamo is made to run, the more electric power it can be designed to produce; or, in other words, the greater its *output*, so that a high-speed dynamo requires less copper and iron: i. e., less weight and material, than a slow-speed dynamo of the same power. It can, therefore, be usually constructed at a smaller cost. It is, however, becoming customary to introduce direct-driven generators in large isolated plants with fairly fast-running engines and heavy dynamos. Such a plant can be constructed, quiet in its operation, simple and strong in its parts, and comparatively inexpensive to operate and maintain.

A direct-driven, Western Electric dynamo, suitable for isolated plant service, is shown in Fig. 1. Here the engine is of the horizontal non-condensing type. The main shaft of this engine carries on one side the fly-wheel F, containing a governor G, and on the other side the armature A, of the dynamo. The dynamo is mounted on a cast-iron bed-plate, united solidly with the bed-plate of the engine, and the main shaft of the engine is extended through the armature bearing B. This bearing is provided with adjusting bolts *b*, *b*, for setting and keeping the bearing in perfect alignment.

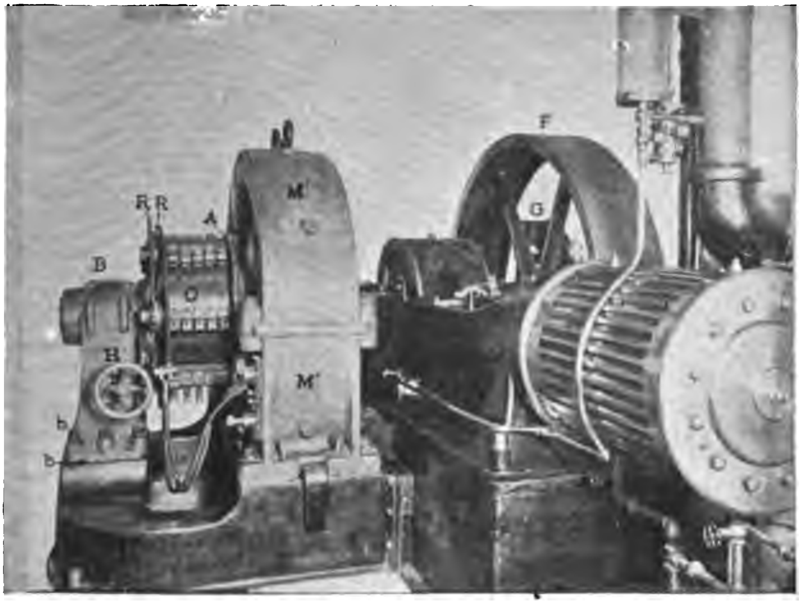


Fig. 1—Direct-Driven Western Electric Dynamo, Connected to Ball and Wood Engine, Suitable for Isolated Plants.

The armature A, rotates within the space provided between the pole pieces of the ***field magnets.*** These magnets are supported on a circular yoke or frame M′ M′. This machine has six poles, and is, therefore, a ***multipolar machine;*** i. e., a machine having more than a single pair of poles. The field frame M′ M′; is better shown in Fig. 2, which gives a side view of the same machine. There are six sets of brushes, each set including five carbon brushes. These brushes are supported each in a separate brush-holder provided with a spring,

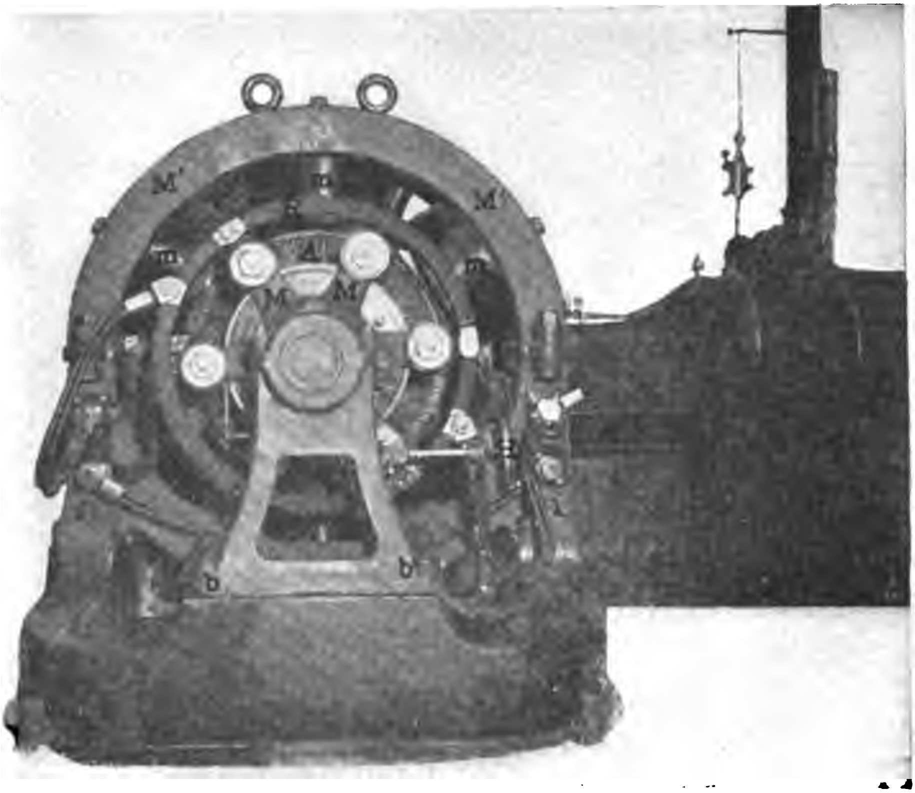


Fig. 2—Direct-Driven Western Electric Dynamo, Suitable for Isolated Plant.

so as to maintain a uniform pressure between the face of the brush and the commutator C. The sets of brushes are all held securely in a star-shaped frame M, but are insulated from the same by insulating washers. The sets of brushes are connected by two metal rings R, R, Fig. 1, three to the one ring, and three to the other, alternate sets being connected to opposite rings. One ring thus connects the three positive brushes, and the other ring the three negative brushes. The two rings are carefully insulated from each other, since their connection would short circuit the armature. The star-shaped frame and the rings form one piece, which is capable of being rotated around the axis of the armature, through a suitable small range, by the handle H.

This adjustment is for the purpose of setting the bushes at the non-sparking point when the dynamo is under load. Under ordinary conditions of working; i.e. within the limits of full load, the brushes do not require to be moved, but at overloads a readjustment in the position of the brushes on the commutator may be needed.

The armature windings consist of solid copper bars surrounded by insulating tubes which are inserted in slots on the surface of the armature-core. The end-connectors are formed of stampings of solid copper with loops formed in their ends. These end-connectors serve to join the solid copper bars in the proper sequence to form the armature winding. The loops on the end-connectors are forced over the ends of the bars and soldered thereto, by running molten solder through an eye in the loop until it is seen to exude on both sides of the loop. This form of armature winding permits any individual part to be taken out separately in case of accident. All the end-connectors are supported on the inside by lugs secured to an insulating ring on the hub.

The dimensions and weights of these dynamos is seen in the accompanying table.

Another example of a direct-driven dynamo; namely, a Walker generator for isolated lighting, is shown in Fig. 3. In this particular case the dynamo is mounted on the right

TABLE OF DATA OF WESTERN ELECTRIC COMPANY'S DIRECT-DRIVEN DYNAMOS.

Kilowatts.	Poles.	Speed.	Volts at Full Load.	Amperes at Full Load.	Shipping Wt. in Pounds.	Floor Space. Perpendicular to Shaft.	Floor Space. From Engine Bearing or Fly-Wheel to End of Outboard Bearing.
						Inches.	Inches.
5	4	650	120–240	40– 20	1200	27	25½
9	4	350	120–240	75– 37	2530	35½	36½
15	4	350	120–240	125– 62	2900	35¾	34
20	4	300	120–240	165– 85	5000	47	38¼
25	4	350	120–240	210– 105	4990	43½	38
25	4	300	120–240	210– 105	6150	$45\frac{5}{16}$	39
30	4	400	120–240	250– 125	4990	43½	39¾
30	4	300	120–240	250– 125	6150	$45\frac{5}{16}$	40
35	4	275	120–240	290– 145	6450	$46\frac{13}{16}$	43
40	4	310	120–240	330– 170	6450	$46\frac{13}{16}$	43
50	4	460	120–240–550	420– 210– 90	6940	$46\frac{13}{16}$	44½
50	6	275	120–240–550	420– 210– 90	8570	62	40
60	6	460	120–240–550	500– 250–110	6400	52	42
60	6	275	120–240–550	500– 250–110	8920	62	40
75	6	300	120–240–550	625– 310–130	10430	62	50
75	6	275	120–240–550	625– 310–130	11000	65½	48¼
75	6	250	120–240–550	625– 310–130	12930	65½	56¾
75	6	200	120–240–550	625– 310–130	14000	67½	60
100	6	450	120–240–550	830– 420–180	10000	62	48
100	6	250	120–240–550	830– 420–180	15600	69	55¼
100	6	230	120–240–550	830– 420–180	16300	76½	56½
125	6	225	120–240–550	1040– 520–230	17000	76½	57¼
150	6	280	120–240–550	1200– 600–270	21000	74	88¼
200	6	150	240–550	730–320	32000	103	63½
250	10	100	240–550	1040–455	40000	143	6
500	10	100	240–550	2080–910	60000	158	662¼

hand side of the engine, instead of on the left hand, as in Figs. 1 and 2. This is also a six-pole dynamo with six sets of brushes. In practically all cases the number of sets of brushes is the same as the number of poles; for, although it is possible so to wind or connect the armature that a single pair of brushes may suffice, as in the case of Fig. 25, yet the brushes and commutator in such cases are apt to become overheated unless the commutator is made so long, and the brushes so heavy and numerous, that the two sets of brushes

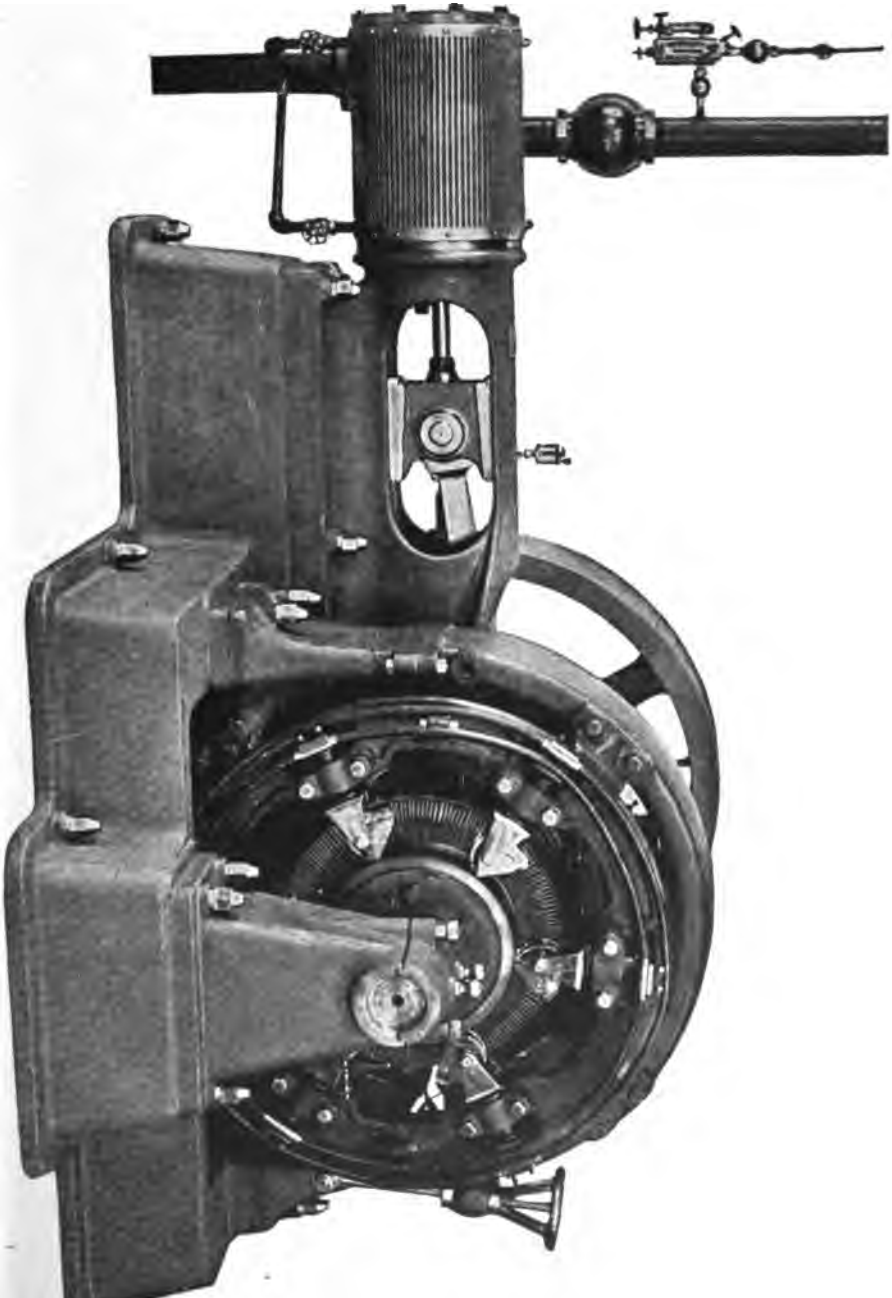


Fig. 3—Walker Company's Direct-Connected "Short" Dynamo for Isolated Lighting.

are more troublesome than when a number of brushes are employed, distributed around the commutator.

A form of brush-holder employed in the Walker dynamo is represented in Fig. 4. Carbon brushes are used and these are set and shaped as shown. The dimensions of the Walker dynamos are given in the accompanying table, which will be understood by reference to Fig. 5. It will be seen that the speed is 300 revolutions-per-minute, in machines of 25 kilo-watt size, and 225 revolutions-per-minute in those of 150 kilo-watt size. The *kilo-watt* is 1,000 watts, and is, approximately, 1⅓ horse-power, the watt being 1/746th of a horse-power, and the kilo-watt, one thousand 746ths=1.34 H. P. If the output of a machine in kilo-watts be increased by one-third, we obtain very closely its output in electrical horse-power. The advantage of using the term kilo-watt lies in the fact that if we multiply the current strength in amperes, which a machine will deliver at full load, by the pressure in volts at the

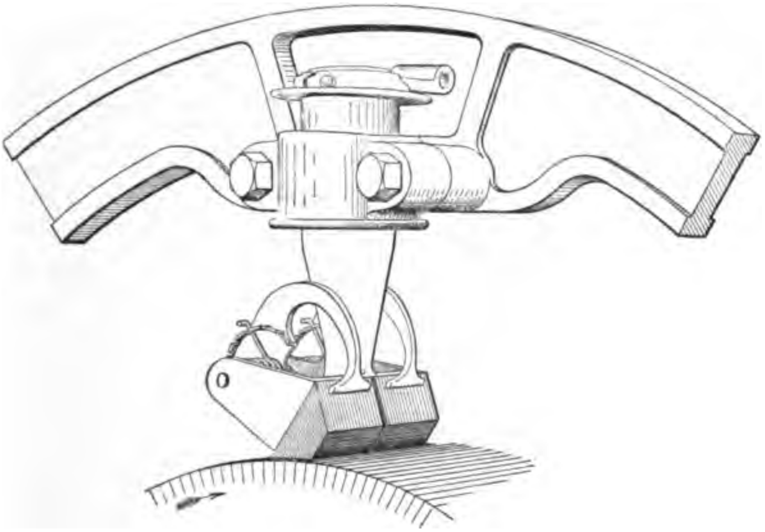


Fig. 4—Walker Company's "Short" Brush Holder.

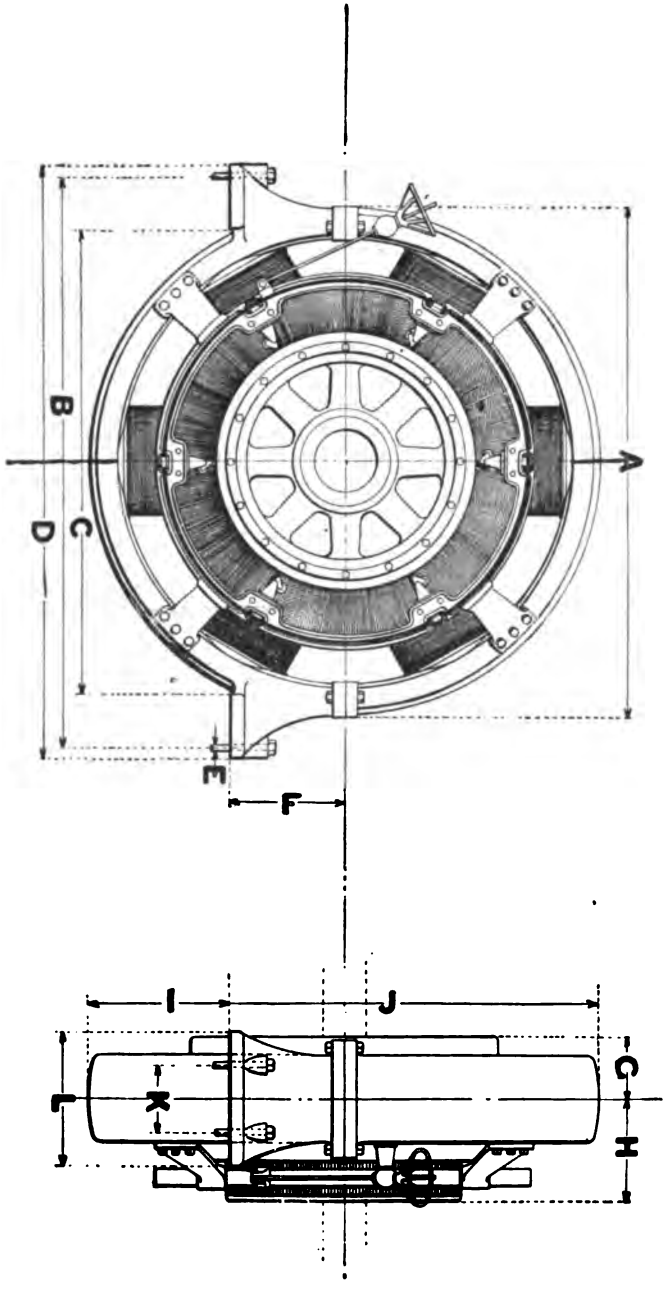


Fig. 5—Dimensions of Walker Company's Direct-Connected Dynamo for Isolated Lighting.

machine terminals, the product will be the electrical output of the machine expressed in watts. Thus, a 150 kilo-watt machine, is a machine which will deliver 150,000 watts output. If the maximum voltage at the machine terminals be 120, the current strength which it will supply at full load will be $\frac{150,000}{120} = 1,250$ amperes. It will be seen from the table that these machines have an output, per pound of weight, varying between 5.7 and 6.4 watts per pound, according to the size of the machine.

TABLE OF DATA OF WALKER COMPANY'S DIRECT-DRIVEN DYNAMOS.

Output.	**KW**	25	50	75	100	150	**KW**	25	50	75	100	150
	E.H.P.	33	67	100	135	200	**F**	15	18	26	27	24
	SPEED	300	275	250	250	225	**G**	7¾	8½	10¼	10¾	11¾
	WEIGHT	4400	6700	15700	18200	23340	**H**	16	18	19	20½	21½
	A	47¾	54¾	73½	76½	80¾	**I**	8¾	9¼	10¾	11¼	16
	B	52	56¾	85	86½	88	**J**	38¾	45¼	62¾	65	64
	C	40	43	56	58	67	**K**	8	13	15	14	13½
	D	54	59	88	89½	91	**L**	18	18	25	25	27
	E	1	1	1½	1½	1½						

Fig. 6, shows a Siemens and Halske multipolar direct-connected dynamo suited for isolated service. This machine is of 40 K. W. output, and is directly connected to a tandem compound engine. The field magnets are placed inside the armature, instead of on the outside as in most American machines. The armature windings form the segments of the commutator, so that the brushes B, B, rest directly upon the external surface of the armature. There are four magnet poles in the machine, supported on a radial iron frame FFFF, Fig. 7, forming the alternate north and south poles n, s, n, s. This field frame is firmly attached to the bed-plate, and around it the armature AA is revolved. The outer surface of the armature, which is free from insulation and constitutes the commutator, has four sets of brushes B, B, B, B, Figs. 6 and 7, corresponding to the four magnet poles. The opposite pairs of brushes are connected together electrically to constitute each one terminal of the machine. Thus, the upper and lower brushes may be connected together to form the positive pole of the armature, and the right and left hand brushes, similarly connected together, to form the negative pole. The brushes are of copper for pressures up to 250 volts, but for pressures above 250 volts, carbon brushes are frequently used. Each set of brushes B, has its individual brushes so clamped along the brush-holder bar, as regards the position of the individual brushes of the other

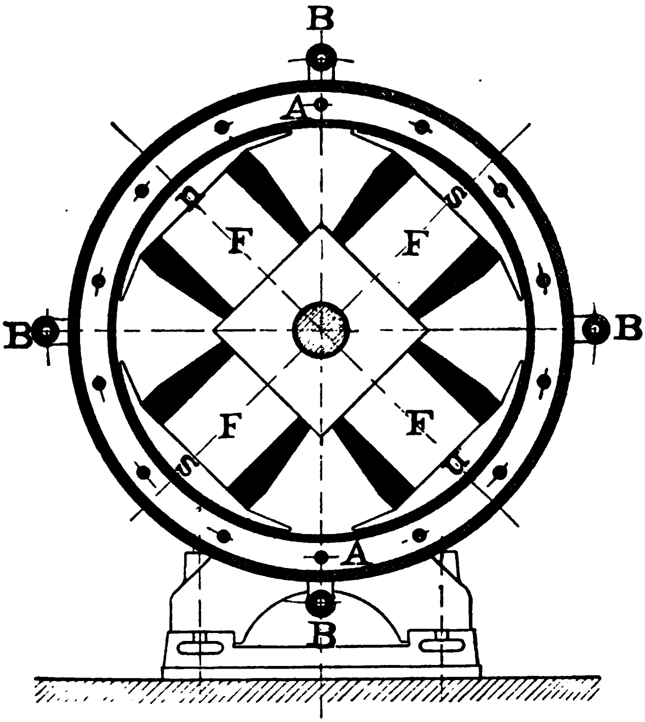


Fig. 7—Cross Section of Armature and Internal Field-Frame of Siemens and Halske Dynamo.

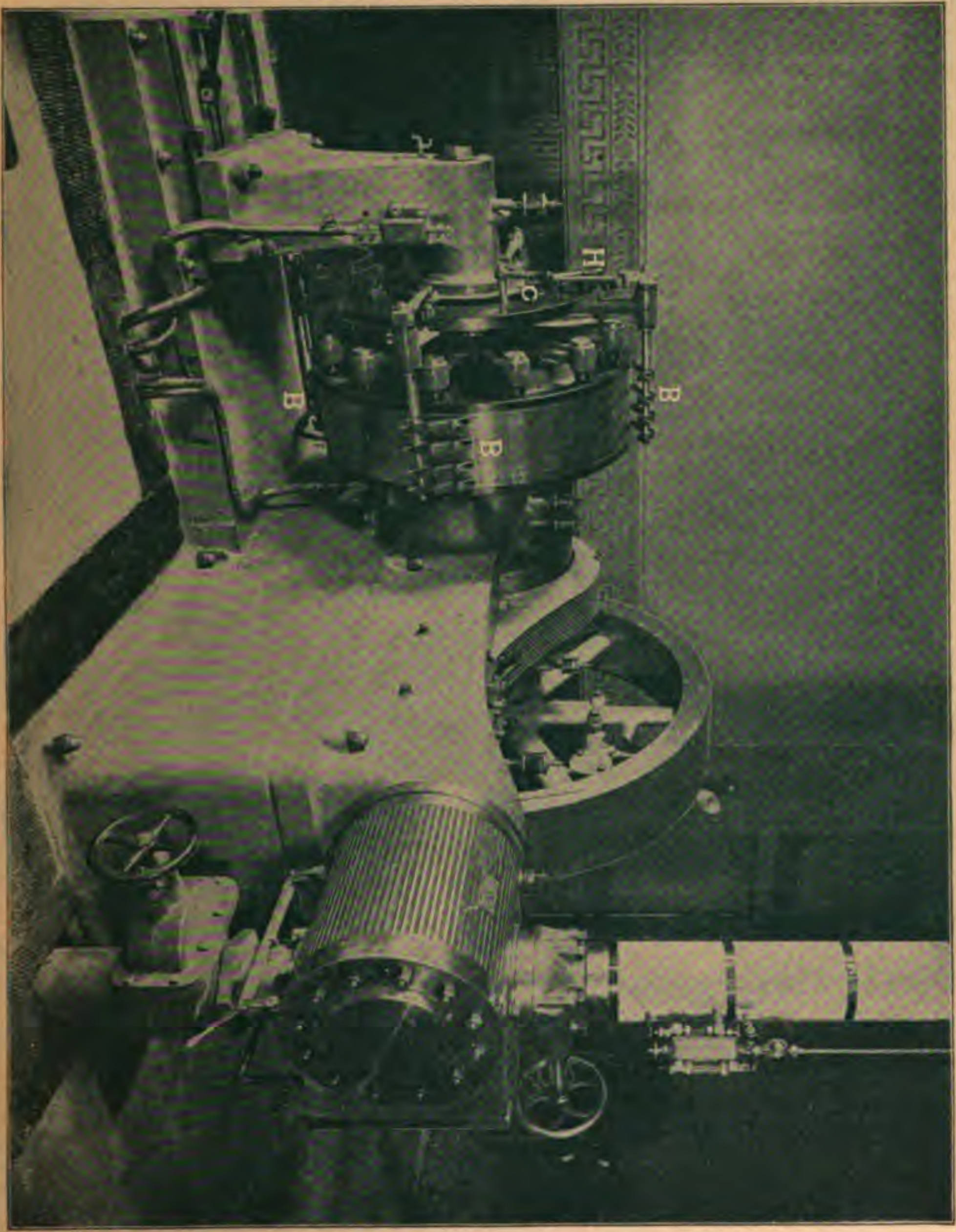


Fig. 6—A Siemens and Halske Multipolar Direct-Connected Dynamo Suitable for Isolated Service.

sets, that all portions of the commutator surface are exposed equally to the friction of the brushes and the injurious formation of ruts or grooves is thus avoided. In all direct-connected dynamos, the proper care of the commutator is a matter of considerable importance, because practically no other part of the machine, except the bearing, is liable to wear, and carelessness in the setting and working of brushes may greatly shorten the life of an armature, or at least render frequent repairs necessary.

In Fig. 6, it will be seen that there are three handles for operating the brush-holders. The lever handle H, serves to rotate the rocker arm, or brush-holder frame, so as to move all the brushes either further forward or further backward, in order to diminish the sparking of the machine at different loads. Another handle serves to rotate all the brush-holders

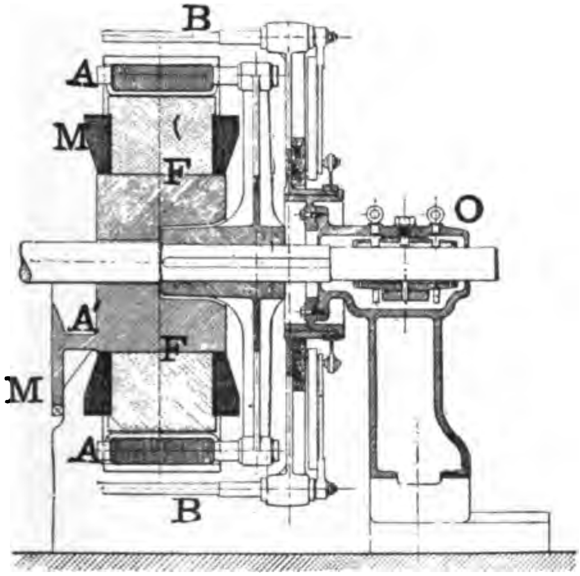


Fig. 8—Longitudinal Section of Siemens and Halske Direct-Driven Generator.

arms in their sockets, and so lifts or depresses all the brushes at the same time. A third handle serves as a clamp.

A longitudinal section of the machine is shown in Fig. 8. Here, FF, is the field frame supported by the arm A′. AA, is the armature, directly attached to the main shaft of the engine; B, B, are the brush-holder arms, and O, the outside bearing.

The Westinghouse Electric and Manufacturing Company's type of direct-connected dynamo, suitable for large isolated plant work in mills and factories, especially where motors and arc lights have to be operated, is shown in Figs. 9 to 14. This is a direct-connected generator usually constructed in sizes from 150 to 400 kilo-watts, and wound for 250 volts at terminals. In Fig. 9, the generator is represented as directly connected to a tandem compound condensing engine in the Duquesne mills of the Carnegie Steel Company. The arma-

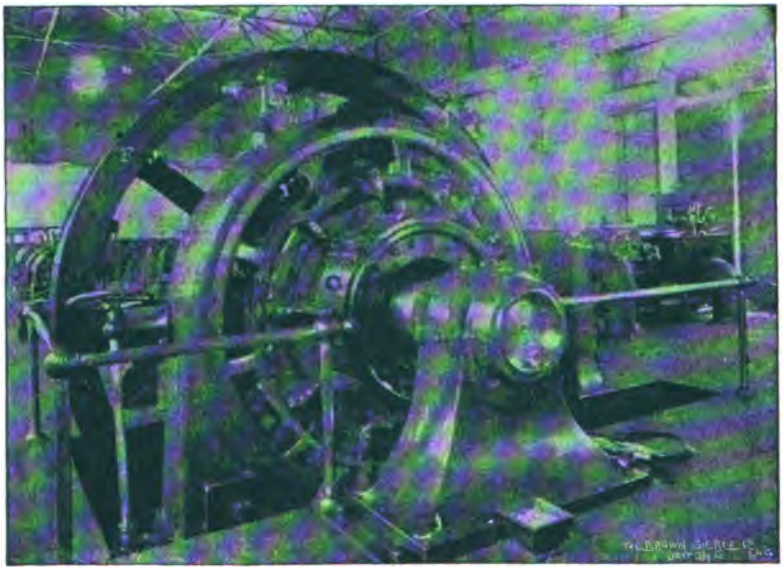


Fig. 9—"Westinghouse" Engine Type of 250-volt Continuous-Current Generator.

ture is mounted on the main shaft of the engine. Between the engine and dynamo is a large fly-wheel F. The machine is supported upon a foundation situated below the main floor, in which a pit is provided for ready access to the brushes b. These brushes are of carbon. There are five in each set, and ten sets on the commutator C, since the machine has ten poles.

The armature core C C, for the machine shown in Fig. 10, is represented as built up of annular sheets of soft, annealed steel, and constitutes what is called a *laminated core.* These sheets are formed of punched discs and are assembled together on an iron spider SSS, supporting both the armature core and the commutator, which is mounted upon the cylinder YY. The armature core-discs are compressed between two end plates, one of which is visible in Fig. 10, at e. It will be seen that five ventilating spaces are provided, extending circumferentially around the armature core, for the purpose of cooling the armature when under load, by throwing air

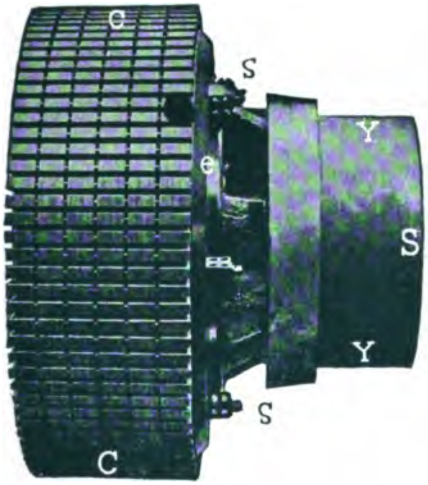


Fig. 10—Armature Core of Westinghouse” Direct-Driven 250-volt Generator.

under centrifugal force from the interior of the spider through the body of the armature. The completed armature is represented in Fig 11. Here, the slots in the surface of the armature core are seen to be filled with the armature winding, which is made from bars of drawn copper. These bars after being shaped, are insulated and baked to remove moisture from the insulation. Any armature coil can be readily removed if necessary. The pole-pieces are of laminated steel.

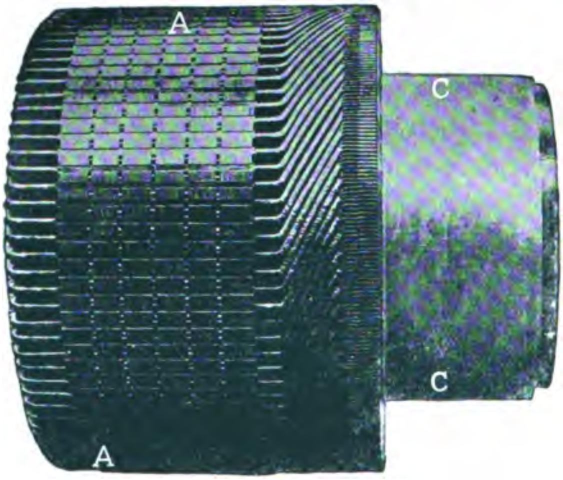
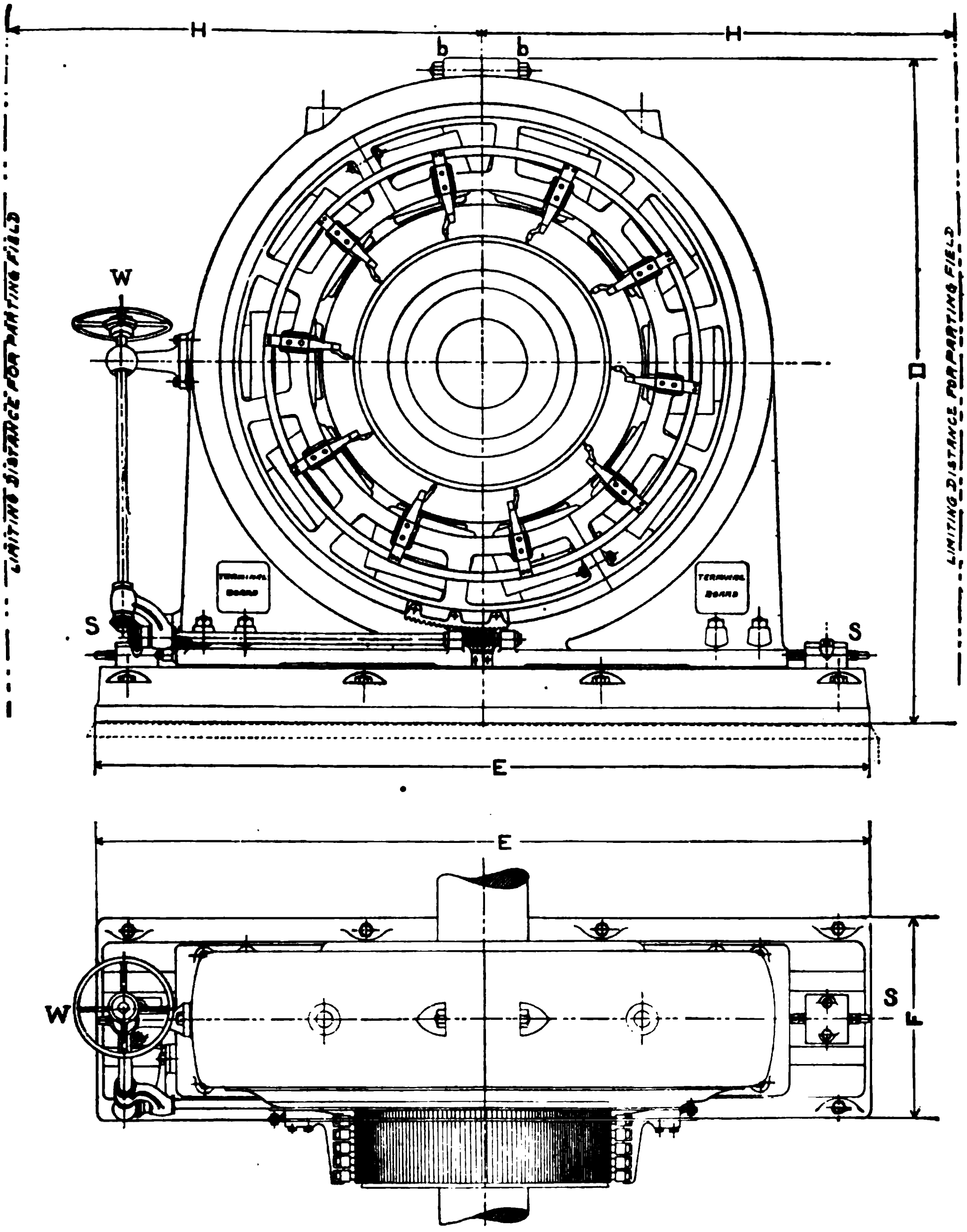


Fig. 11—Completed Armature of "Westinghouse" Direct-Driven 250-volt Generator.

Figs. 12, 13 and 14, show the general structure of The Westing-house Electric and Manufacturing Company's 250-volt direct-driven generators, with letters of reference, showing, when taken in connection with the accompanying table, the dimensions of four different sizes. It will be seen that the machines have either 8 or 10 poles. The output, per pound of net weight, is from $6\frac{1}{4}$ to 8 watts per pound, according to size. The speed of driving varies from 200 to 130 revolutions per minute. The wheel W, adjusts the position of the rocker arm, or circle carrying all the brushes, and moves them for-


H
H
b
b
W
S
S
D
LIMITING DISTANCE FOR PARTING FIELD
LIMITING DISTANCE FOR PARTING FIELD
TERMINAL BOARD
TERMINAL BOARD
E
E
W
S
F

Figs. 12 and 13—Diagram of Dimensions of "Westinghouse" Direct-Connected 250-volt Generator.

TABLE OF APPROXIMATE DIMENSIONS OF WESTINGHOUSE ELECTRIC COMPANY'S 250-VOLT DIRECT-DRIVEN GENERATORS.

KW.	Amperes at 250 Volts.	No. of Poles.	R.P.M.	Approx. Net Weight.	A	B	C	D	E	F	G	H
					In.	In.	In.	In.	In.	In.	In.	In.
150	600	8	180–200	24,000	15½	33	51¼	94¼	120	36	42	96
200	800	8	170–185	30,000	17	34	54¾	101	120	36	45½	96
300	1200	8	145–160	43,000	17	39	62½	114½	144	39	52¾	108
400	1600	10	130–142	50,000	18	38	67¼	124¼	144	39	57	114

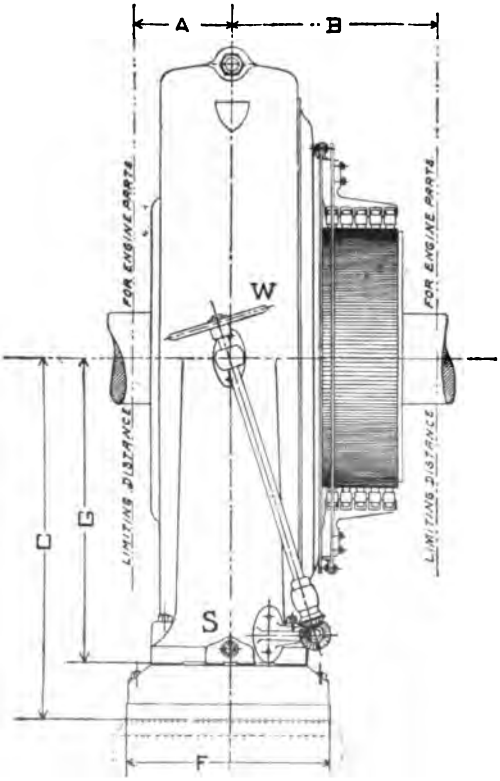


Fig. 14—Diagram of Dimensions of "Westinghouse" Direct-Connected 250-volt Generator.

ward or backward through a small angular range, so as to ensure quiet commutation. The field frame is made in two vertical halves which are bolted together by bolts b, b. In order to obtain ready access to the armature, the two halves of the field frame may be withdrawn by releasing these bolts and operating the screws S, S. By this means the two halves are separated along ways in the bed-plate.

The brushes are of carbon and are supported in brackets from the surface of the rocker-arm circle. There are five brushes to each set, and 8 or 10 sets of brushes, according to the number of poles.

Another feature of the Westinghouse armatures, when above 75 K. W. output, is the ring connection of their armatures. Four conducting rings, which are insulated from each other, are employed in the armature. To these rings are connected corresponding points in the armature winding as indicated diagrammatically in Fig. 15. Here a six-pole field P_1, P_2, P_3, P_4, P_5, P_6, surrounds an armature ring shaded in the figure. This is connected in the usual way with its commutator by connections not shown in the diagram. The armature winding is, however, tapped at the corresponding points a, a_1, a_2, and connected to conducting ring No. 1. Similarly, the points b, b_1, b_2, are connected to ring No. 2; c, c_1, c_2, to ring No. 3, and d, d_1, d_2, to ring No. 4. If the poles P_1,—P_6, are all equally strong, and the armature is symmetrically placed with respect to them, these ring connections will have no effect, since no current will pass through any of the conductors shown. If, however, any pole, say P_4, is unduly strong or weak, currents will be set up in the segment of the armature lying beneath the pole, in such a manner as to compensate for the irregularity and, therefore, to aid in re-establishing magnetic symmetry.

Another feature of the Westinghouse direct-current generators, adopted in machines above 25 K. W. capacity, is a method of magnetically saturating the pole-edges n, n, s, s, Fig. 15, so as to prevent distortion of the magnetic flux-distribution by the magnetic influence of currents in the armature under load. This enables the brushes to be maintained in a fixed position through wide variations of load, and greatly reduces the loss of energy in the teeth of the armature core due to magnetic reversals, when under load. The method consists in cutting off the pole corners of from half to two-thirds of all the laminated plates which, when assembled, make up a pole piece. Consequently, the pole pieces retain full thickness over about the middle third of their length, where all the sheets unite, but at the pole corners, only alternate sets of sheets may be left, and the cross-section of the pole-edges is thus virtually halved, thereby correspondingly increasing the

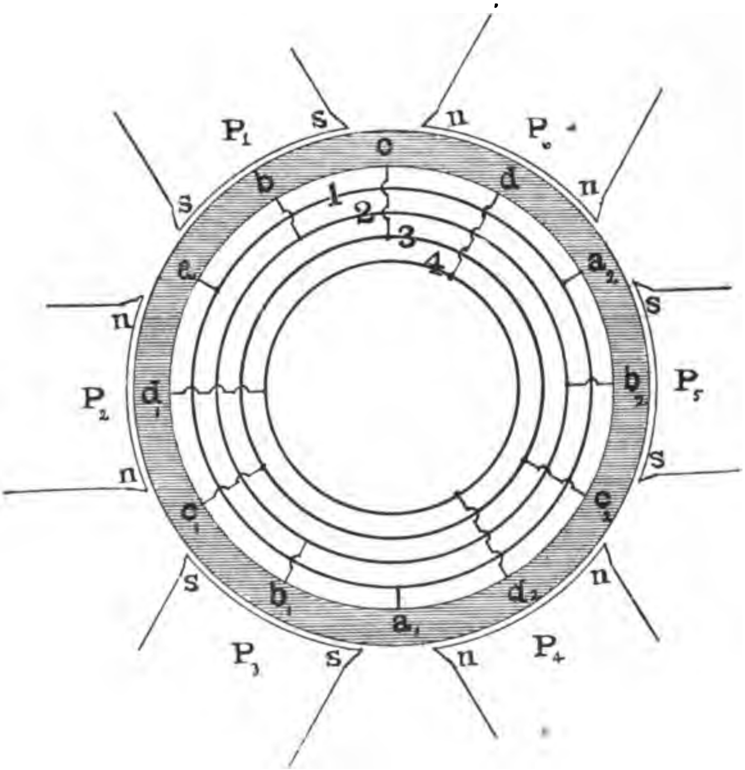


Fig. 15—Diagram of Ring-Connected Armature.

density of the magnetic flux passing through them. The magnetically saturated polar edges oppose marked resistance to the magnetic influence of the active armature conductors passing beneath the pole-face, and thus greatly lessen cross-magnetization.

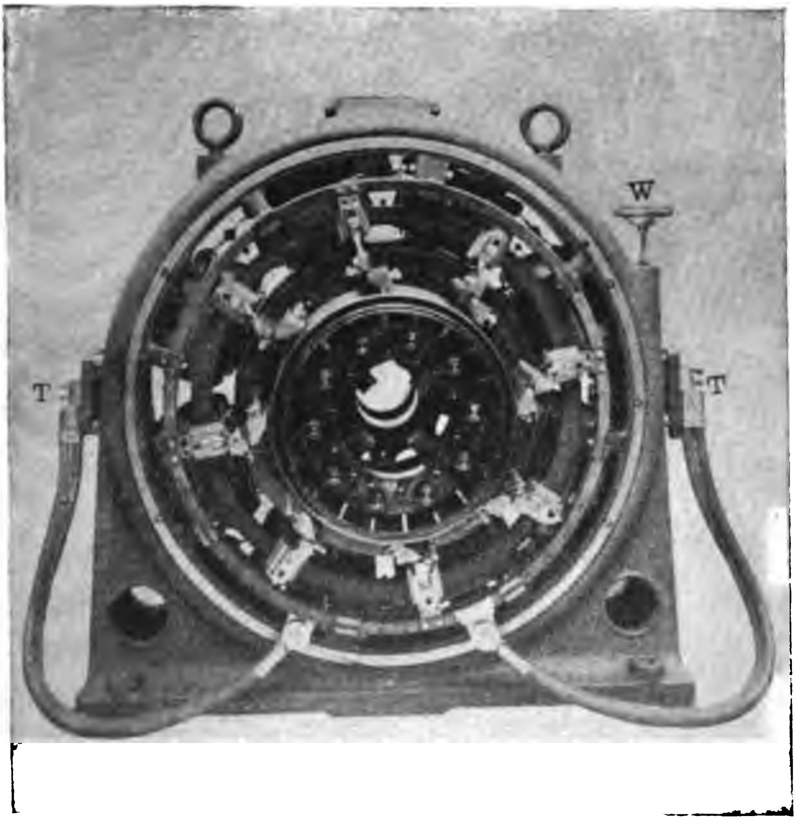


Fig. 16—"Westinghouse" 120 K. W. Direct-Current 125-volt Engine—Type Generator.

Figs. 16 and 16 A, show a Westinghouse Electric and Manufacturing Company's 120 K. W. Direct-Current Engine-Type of Generator, wound for 125 volts. This is an 8-pole, or *octopolar*, machine, with eight sets of carbon brushes, with four brushes in each set. The brush-holder ring is moved by the wheel W. T, T, are the main terminals, each connected by flexible conductors to an insulated copper ring making contact with alternate sets of brushes. The field is compound-wound, the series coil being furthest from the armature.

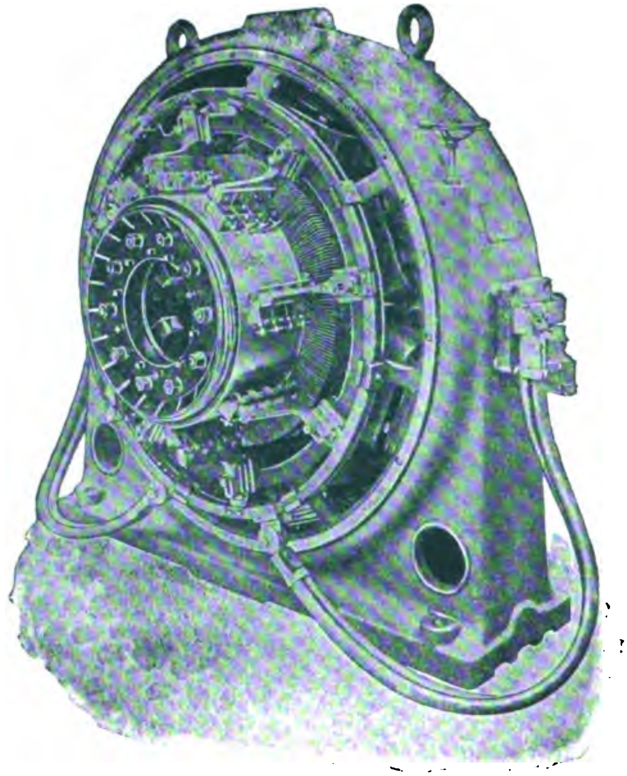


Fig 16 A.—"Westinghouse" 120 K. W. Direct-Current 125-Volt Engine-Type Generator.

The armature of this machine is shown in Fig. 17. It has two ventilating grooves in the body of the core. It has also 91 slots and 273 commutator bars, making about 11 slots and 34 bars per pole of the field; or three bars per slot. Consequently, the full pressure of 125 volts is generated between adjacent sets of brushes, or between the 34 commutator bars which separate adjacent brushes. The average pressure between adjacent commutator bars is, therefore, $3\frac{2}{3}$ volts, a low voltage being an important factor in securing sparkless commutation. This, however, is by no means the only circumstance which controls sparkless commutation, since some special forms of machines generate an average of several hundred volts between adjacent commutator bars, while some arc-light generators with open-circuit armatures; i. e., armatures provided with coils that are disconnected from the circuit, or are on open-circuit during a certain portion of each

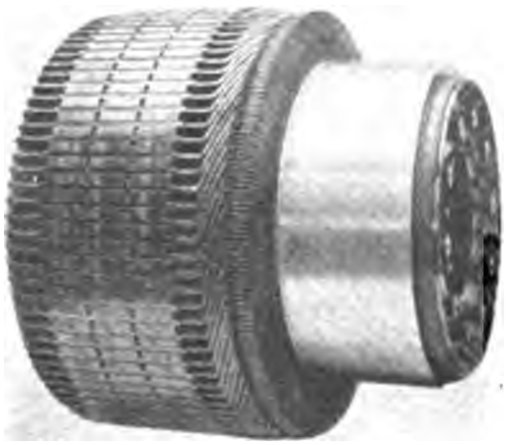


Fig. 17—Armature for "Westinghouse" 120 K. W. Direct-Current 125-volt Engine-Type Generator.

revolution, maintain an average of several thousand volts between adjacent commutator bars.

A similar type of Westinghouse Electric and Manufacturing Company's direct-driven generator, called the Standard Engine Type, is represented in outline in Fig. 18. These machines are usually wound for 125 volts. The accompanying table gives their dimensions. They have slotted, venti-

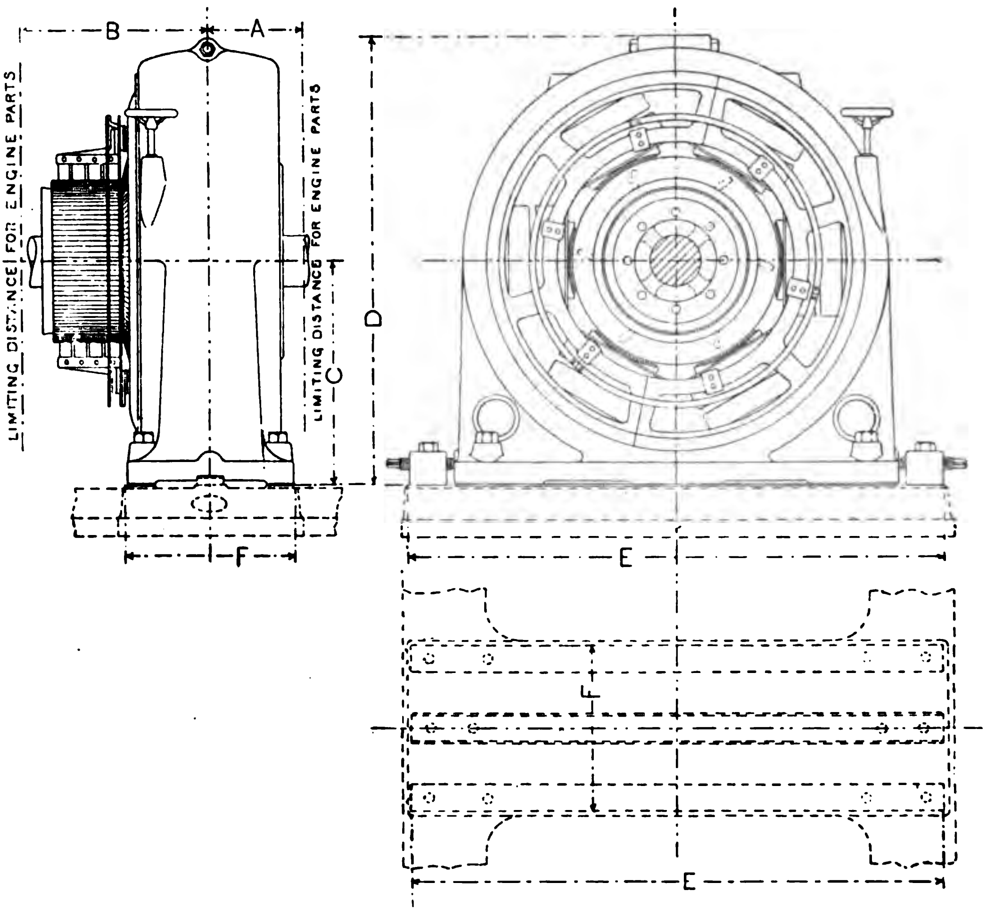

B
A
LIMITING DISTANCE FOR ENGINE PARTS
LIMITING DISTANCE FOR ENGINE PARTS
C
D
F
E
F
E

Fig. 18—"Westinghouse," Direct-Driven Engine—Generator.

lated, ironclad armatures and field frames in two vertical halves, movable on ways. All have six poles except the 100 K. W. machines, which have eight poles.

TABLE OF STANDARD SIZES AND APPROXIMATE DIMENSIONS OF WESTINGHOUSE ELECTRIC COMPANY'S DIRECT-DRIVEN ENGINE-TYPE GENERATORS.

K. W.	Amperes. 125 Volts.	Revolutions Per Min.	Approximate Net Weight In Lbs.	A	B	C	D	E	F
25	200	320-350	5,400	9″	17¾″	22½″	44¼″	53″	15¾″
37½	300	290-320	4,400	9¾″	18⅛″	24″	47¾″	56½″	16¾′
50	400	275-300	5,900	10¼″	21″	26″	51¾″	61″	17¾′
62½	500	275-300	6,800	11″	21″	27¼″	54½″	67″	19¼″
75	600	265-290	8,500	12½″	24⅝″	30¼″	61½″	73″	22¾″
100	800	250-275	11,000	12½″	27¾″	34¼″	68¼″	80″	21¾″

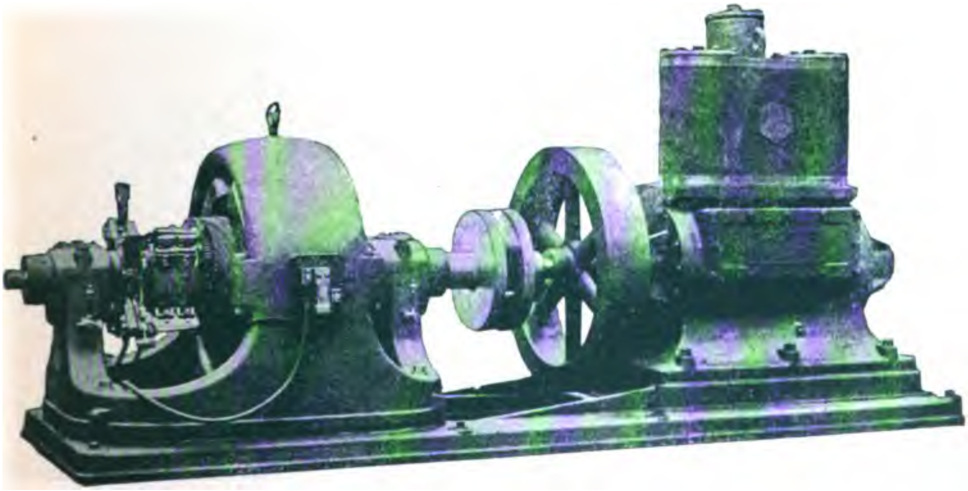


Fig. 19—A "Westinghouse" 37.5 K. W. Kodak Direct-Connected Dynamo.

Fig. 19, shows another type of Westinghouse direct-connected dynamo, called the " Kodak." The machine shown in the figure is of 37.5 kilo-watts capacity; or, approximately, 50 horse-power. These dynamos are constructed from 5 horse-power to the largest sizes. The generator is coupled to the engine main shaft through an elastic coupling, so as to permit of any slight displacement between the engine and generator axes. This coupling consists of a pair of heavy discs, one on the engine shaft, and the other on the dynamo shaft. Pins projecting from each disc into the space between

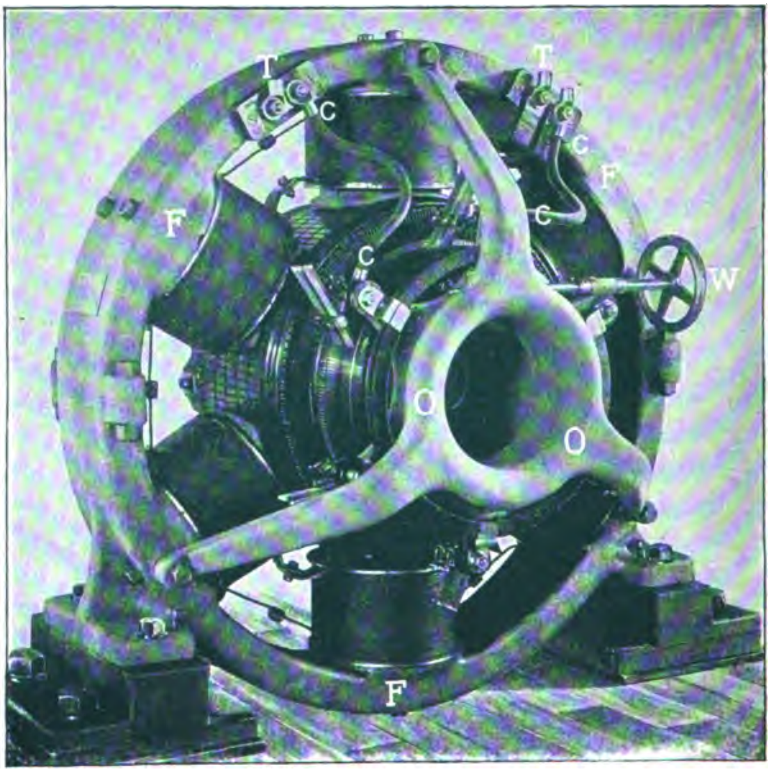


Fig. 20—" General Electric" 6-50-275, Direct-Driven Generator.

them, at different radii, enable short belts or leather loops to connect them flexibly. The generator is of the *quadripolar*, or four-pole type, and is provided with four sets of carbon brushes.

Fig. 20, represents the General Electric Company's type of direct-driven multipolar machine for lighting purposes and

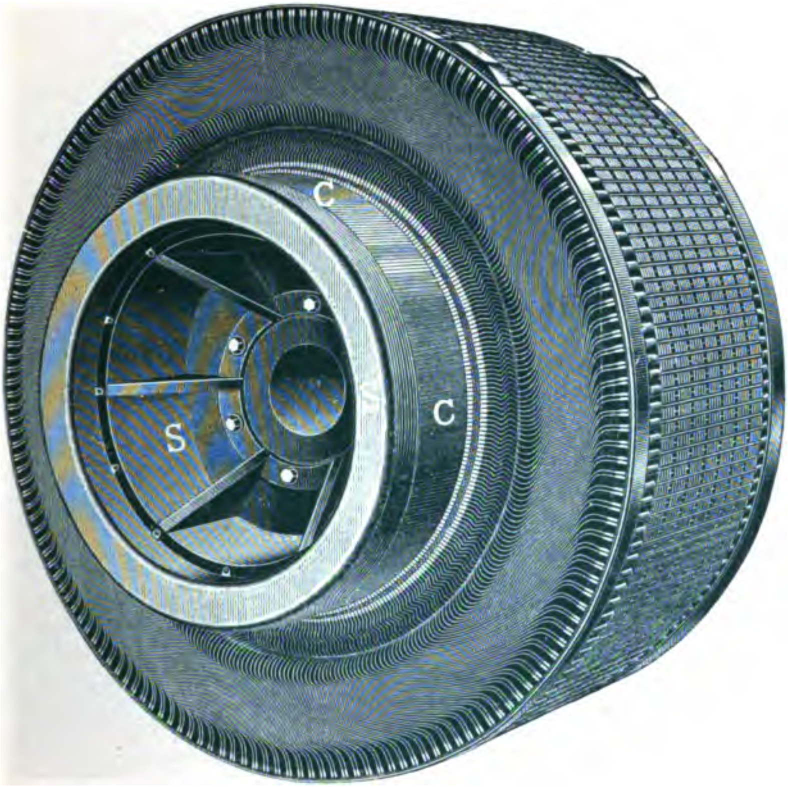


Fig 21—"General Electric" Iron-Clad Armature of Direct-Driven Generator.

isolated service. This machine is of the *sextipolar*, or six-pole type, and is called a 6-50-275 generator, which means 6 poles, 50 kilo-watts, and 275 revolutions per minute.

Here, the field frame FFF, of cast steel, is cast in two halves: OO, is the outside tripod bearing. T, T, are the main terminals to which are attached the cables that carry off the current supplied by the machine. There are six sets of brushes, which are set in the rocker-arm circle, whose position is controlled by the hand wheel W. The brush-holders are alternately connected to two metal rings, which are insulated from each other, and which are finally connected to the main terminals by the copper cables CC, CC.

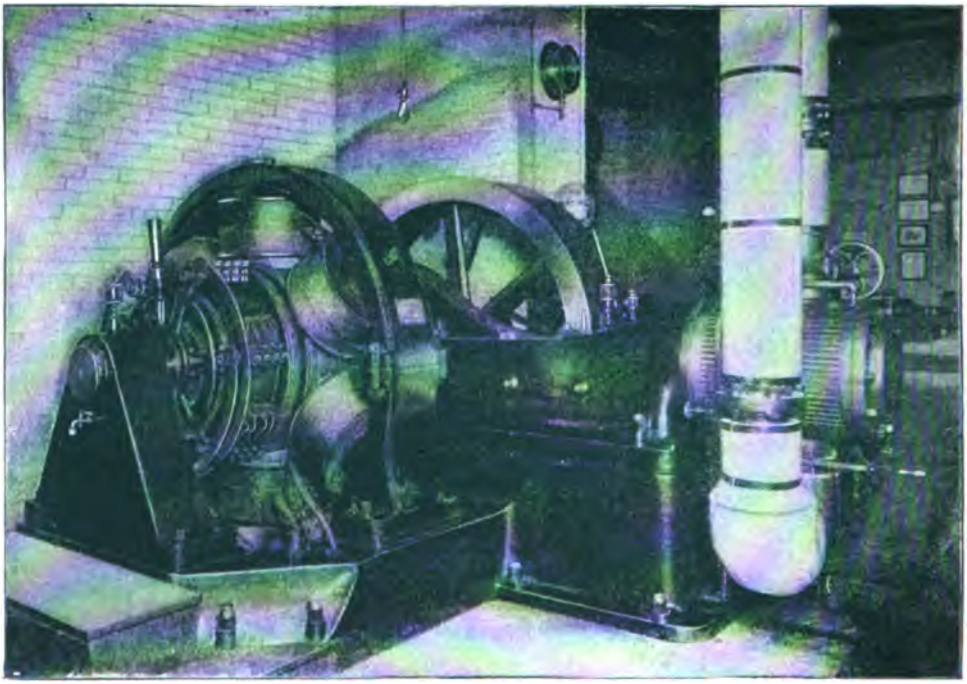


Fig. 21 A—"General Electric" Multipolar Generator.

The iron-clad armature for such a generator is represented in Fig. 21. It will be seen that carefully insulated copper bars are inserted in the slots formed by the assemblage of a number of punched discs of annealed steel. These bars are all connected with the commutator CC. The armature body and commutator are mounted together upon the spider SS, which in its turn is keyed directly to the main engine shaft. The armature is ventilated by slots extending circumferentially around the surface of the armature core.

A more recent type of the General Electric Company's multipolar direct-driven generators, in shown in Fig. 21 A. Here a six-pole compound-wound machine, of 50 K. W. capacity at 275 revolutions per minute, is directly connected to a horizontal engine. The armature of this machine is shown in Fig. 22.

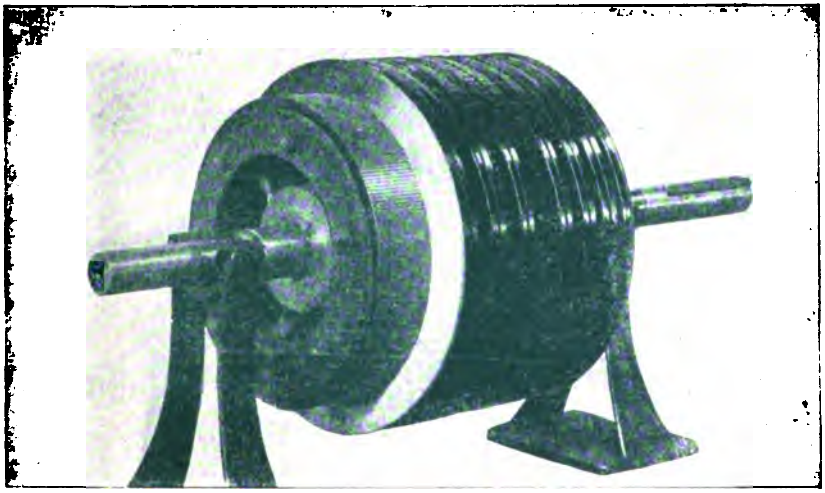


Fig. 22—Armature of "General Electric" Direct-Connected Generator.

This armature is barrel-wound; that is to say, its core or body is provided at each end with a cylindrical flange of cast iron, forming a receptacle for the projecting end connections as shown in Fig. 48. The end connections are carefully insulated from each other, laid symmetrically in the flanges, and then tightly secured in place. The flanges not only afford an excellent mechanical protection for the end connections,

TABLE OF GENERAL ELECTRIC COMPANY'S MULTIPOLAR DIRECT-DRIVEN LIGHTING GENERATORS.

CLASSIFICATION.				FORMS.	OUTPUT AT BRUSHES.		APPROX. H. P. TO DRIVE.	APPROX. WEIGHTS.		DIMENSIONS.				TYPE OF ARMATURE.
Type.	Poles.	K. W.	Speed.		Amps.	Volts.		Armature. Lbs.	Generator. Lbs.	Height to Top of Frame.	FLOOR SPACE. Length.	FLOOR SPACE. Width.	Diam. of Shaft.	
MP	6-	25-	305	F	200	125	40	1,050	3,000	$40\frac{3}{16}$ ″	$39\frac{1}{2}$ ″	$48\frac{1}{2}$″	$3\frac{5}{8}$″	Ironclad using Carbon Brushes.
MP	6-	50-	280	F	400	125	75	2,050	5,550	$51\frac{1}{4}$ ″	$44\frac{7}{8}$ ″	60 ″	5 ″	
MP	6-	75-	270	F	600	125	110	2,600	6,900	$51\frac{7}{8}$ ″	$47\frac{3}{4}$ ″	$62\frac{1}{2}$″	5 ″	
MP	6-	100-	275	F	800	125	150	3,050	8,000	$55\frac{1}{8}$ ″	$53\frac{7}{8}$ ″	68 ″	$5\frac{1}{2}$″	
MP	8-	150-	230	F	1200	125	225	5,050	10,000	$66\frac{1}{4}$ ″	$57\frac{15}{16}$ ″	83 ″	$6\frac{1}{2}$″	
MP	8-	100-	175	D	740	135	150	5,860	23,800	92 ″	35 ″	106 ″	6 ″	Smooth Body with surface Commutator using Copper Brushes.
MP	10-	200-	150	B	1480	135	300	9,600	24,500	99 ″	35 ″	146 ″	9 ″	
MP	12-	400-	100	C	2960	135	600	21.250	54,400	107 ″	37 ″	181 ″	14 ″	
MP	16-	800-	90	B	5920	135	1175	46,500	100,400	150 ″	50 ″	194 ″	18 ″	

or coil ends, but also prevent oil in the bearings from being thrown upon the armature winding.

The accompanying table shows the sizes and dimensions for a number of different machines.

Fig. 23, shows a direct-coupled pair of General Electric Company's Marine Type of Quadripolar Generators, with carbon brushes, wound for 80 volts pressure, and each capable, at 400 revolutions per minute, of delivering 800 amperes. They are coupled to a double engine of the vertical marine type.

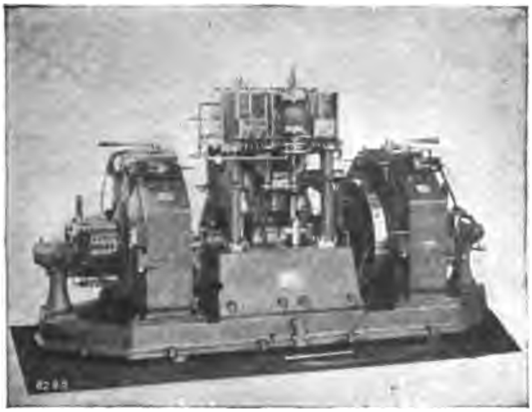


Fig. 23—Pair of "General Electric" Direct-Driven Marine Dynamos.

The current delivered by these machines is employed both for lighting and for turret-turning. A main switch is seen to be mounted on a head-board over each machine. U. S. Navy specifications usually require that the highest temperature obtained by any part of the generators, after sustained full load, shall not be more than 50° F. above that of the surrounding air.

Fig. 24, shows a General Electric Company's, 6-pole 25 K. W., 305 rev. 80-volt, Marine Generating Set, arranged to sustain full load with a rise in temperature on the dynamo not exceeding 25° C. The single-cylinder engine and dynamo are mounted on a common bed-plate, as shown. The governor is placed on the fly-wheel.

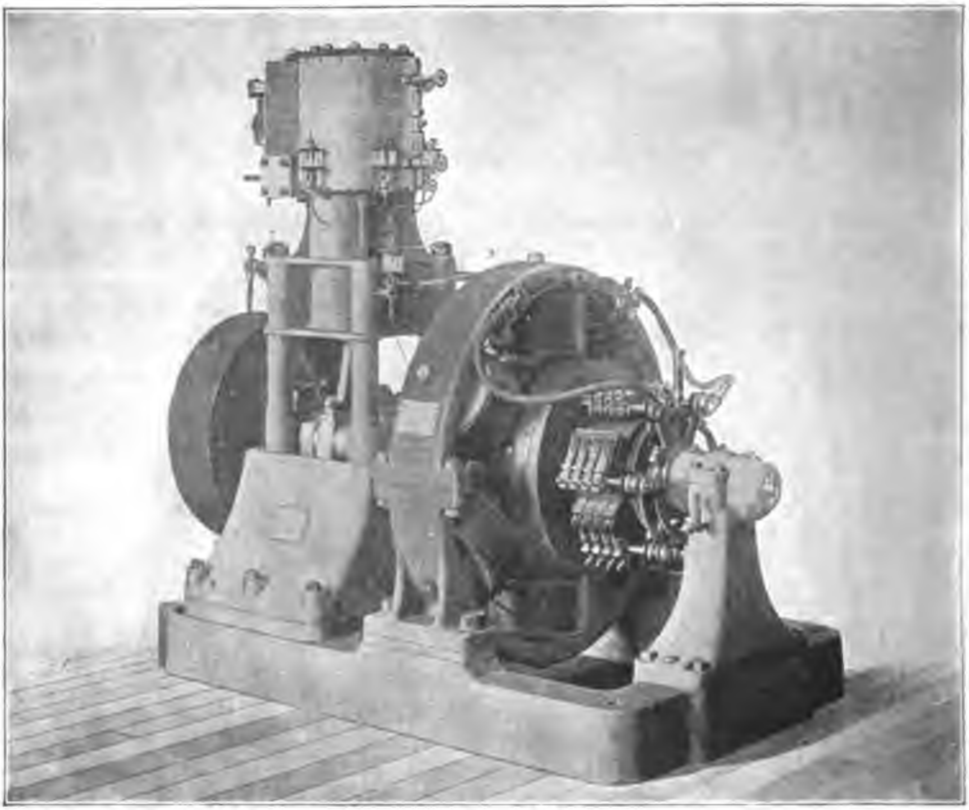


Fig. 24—" General Electric " Marine Generating Set.

Another of the General Electric Company's direct-coupled generating sets, is shown in Fig. 25. These generators are of the quadripolar type up to 15 K.W., and, as shown in Fig. 24, of the sextipolar type in 25 K. W. size. They have round field frames and iron-clad armatures. The machine shown has 4 poles, and has an output of 8 K. W. at 650 revolutions per minute. When wound, as is the standard practice, for 110 volts at terminals, it, therefore, gives $\frac{8{,}000}{110} = 73$ amperes, approximately, at full load. The dimensions of these sets is given in the accompanying table. The output, including weights of both engine and dynamo, is seen to be, approximately, 3½ watts per lb. The machine shewn occupies a floor-space of

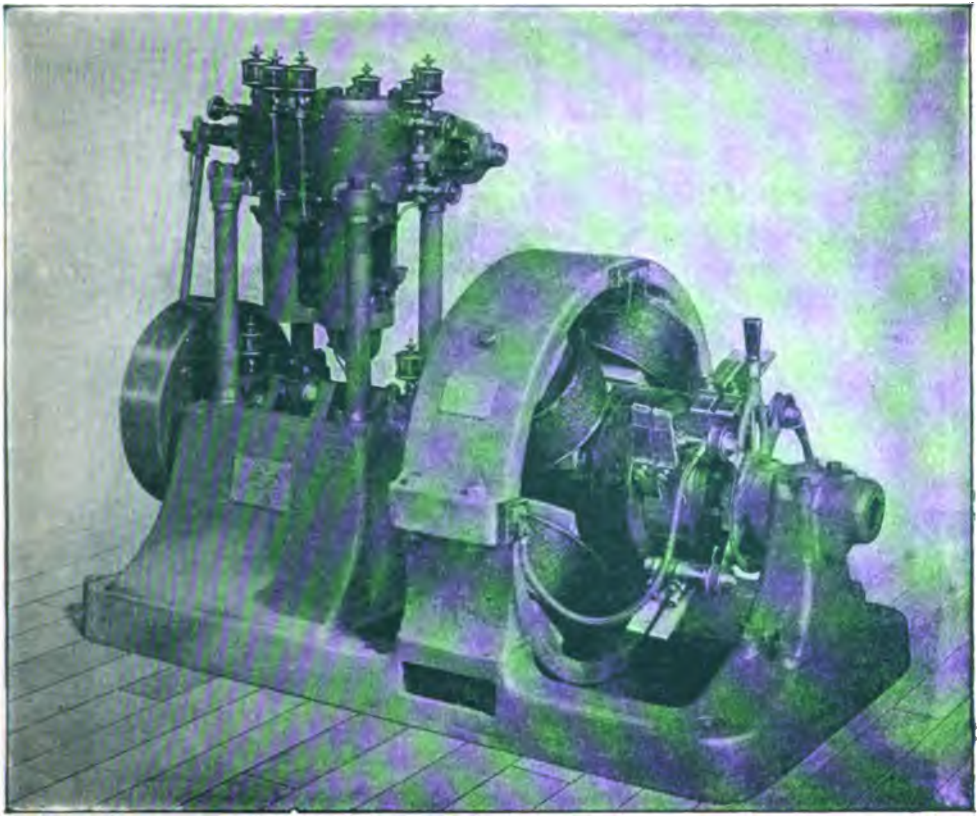


Fig. 25—"General Electric" Direct-Coupled Generating Set, 4-8-650, with Double-Cylinder Engine.

TABLE OF DATA OF GENERAL ELECTRIC COMPANY'S DIRECT-COUPLED GENERATING SETS WITH GENERAL ELECTRIC ENGINES. (COMMERCIAL RATING).

CLASSIFICATION.				Volts. Full Load.	Amperes Full Load.	Floor Space.	Height.	Weight. Pounds.	Steam Pipe Diameter.	Exhaust Pipe Diameter.	Cylinders Diameter.	Stroke.	Type of Engine.	Type of Armature.
Type.	Poles.	K. W.	Speed.											
MP	4-	4-	800	110	36	46″ x 24″	30½″	1,020	1¼″	1½″	3½″	2″½	Double vertical	Ironclad
MP	4-	8-	650	110	73	62″ x 33″	43 ″	2,700	1½″	2 ″	4¼″	4 ″	Double vertical	Ironclad
MP	4-	20-	550	110	182	82″ x 47″	58 ″	5,650	2 ″	2½″	6½	5 ″	Double vertical	Ironclad
MP	4-	2½-	650	110	23	39″ x 23″	32½″	900	¾	1 ″	3½″	3 ″	Single vertical	Ironclad
MP	4-	7-	550	110	64	53″ x 31″	44 ″	2,750	1¼″	1½″	5 ″	4½″	Single vertical	Ironclad
MP	4-	10-	450	110	91	63″ x 33″	52 ″	3,160	1½″	2 ″	6½″	5 ″	Single vertical	Ironclad
MP	4-	15-	400	110	136	72″ x 44″	62 ″	4,700	2 ″	2½″	8 ″	6 ″	Single vertical	Ironclad
MP	6-	25-	305	125	200	80″ x 47″	66 ″	6,500	2½″	3 ″	10 ″	8 ″	Single vertical	Ironclad

5′ 2″ x 2′ 9″ and stands 3′ 7″ high. It weighs 2,700 lbs., with the engine which has two cylinders, each having an internal diameter of 4¼″, with 4″ stroke.

Fig. 26, shows the Triumph Electric Company's 50 K. W. sextipolar generator, directly connected to a horizontal engine. The field frame is divided into vertical halves, connected by large turned bolts fitted into reamed holes. By this means the field frame is readily withdrawn for repairs or inspection.

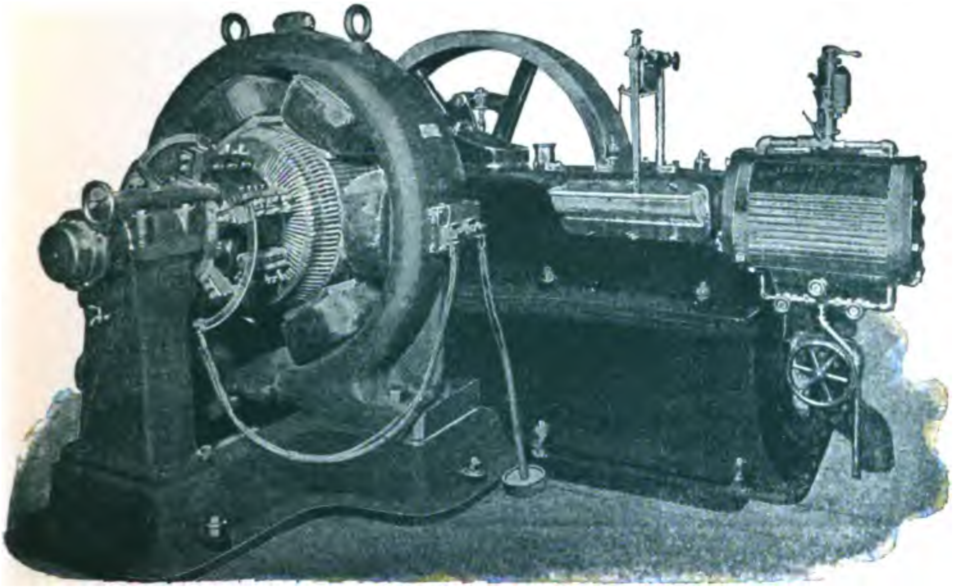


Fig. 26—Triumph Electric Company's Direct-Connected Generator.

The brushes are of carbon and are provided with a positive clamp. The core and completed armature of this generator are seen in Fig. 27, while the commutator and shell of a similar generator are seen in Fig. 28. The ends of the commutator bars are seen to be provided as usual with slots for the reception of the ends of the armature conductors, which are soldered in place.

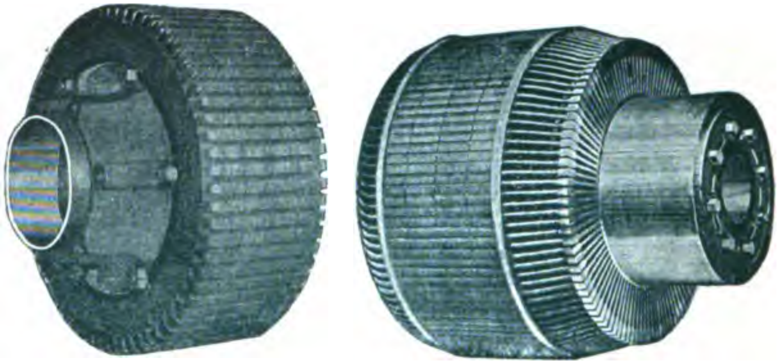


Fig. 27—Core and Completed Armature of Triumph Electric Company's Direct-Driven Generator.

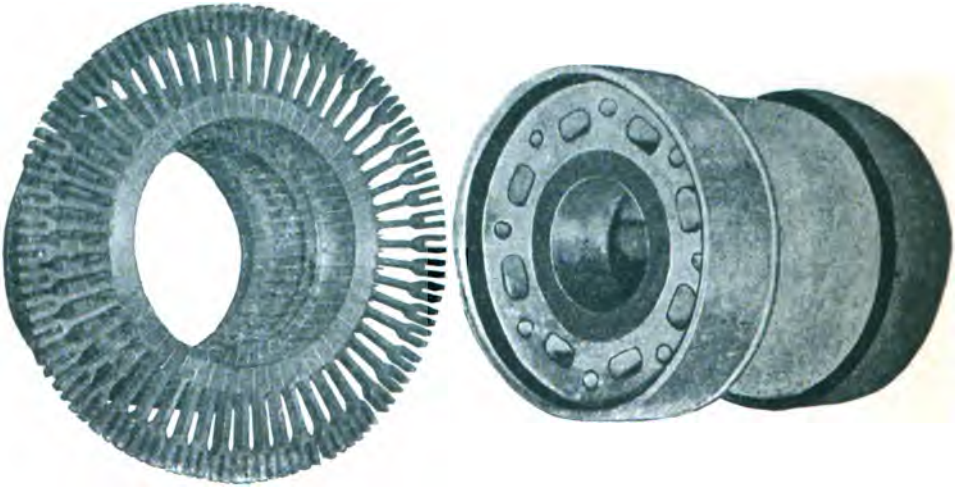


Fig. 28—Commutator and Commutator Shell of Triumph Electric Company's Direct-Driven Generator.

Fig. 29, shows a Bullock Electric Company's, sextipolar compound-wound direct-driven generator, delivering 25 K. W.

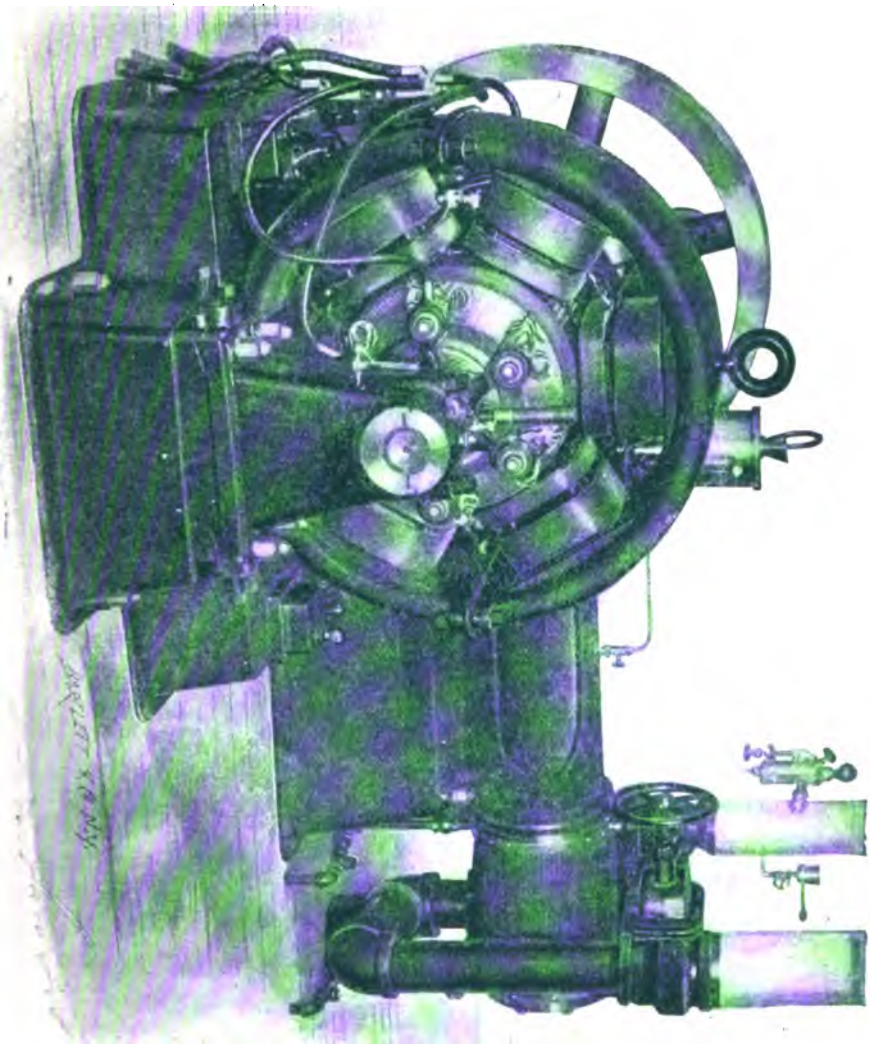


Fig. 20—Bullock Electric Company's Sextipolar Compound-wound, Direct-Driven Generator.

at 275 revolutions per minute. These machines are constructed in the following sizes;—20, 25, 30, 50, 60, 75 and 100 K. W., to run at the standard speed of 275 revolutions per minute. Their carbon brushes are set to a permanent position that calls for no change under variations of load.

A direct-connected 100 K. W. (134 horse-power) generator, of the Crocker-Wheeler Company, is shown in Fig. 30. This shows an octopolar, or 8-pole machine, with eight sets of brushes, the field magnets being mounted directly on the bed-plate of a McIntosh and Seymour engine. The rocker-arm circle supporting the brush-holders, is moved by the wheel handle w. The cables leading from the machine are carried down through the wooden flooring through insulating bushings. The engine and dynamo run at 250 revolutions per minute. The finished armature for this machine is re-

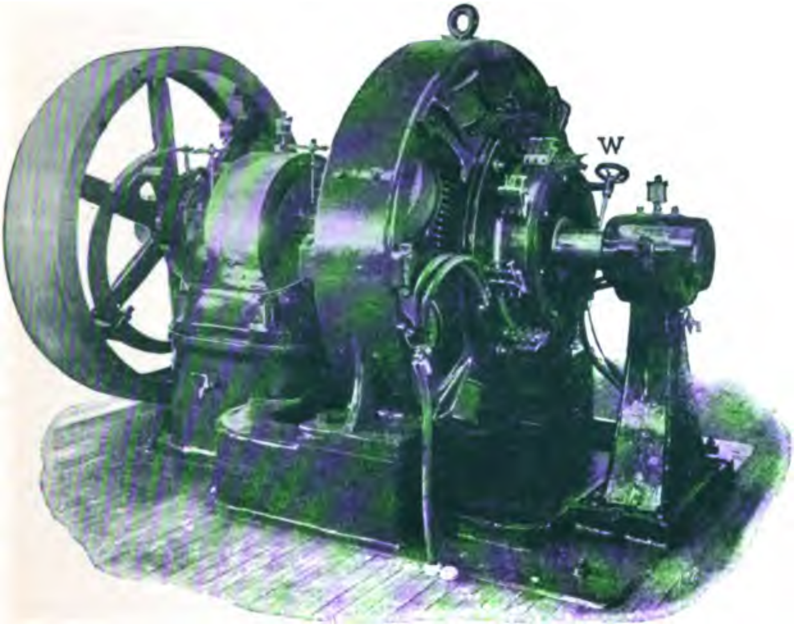


Fig. 30—Crocker-Wheeler Direct-Driven Generator.

presented in Fig. 31. The armature is iron-clad, and the conductors are led through slots on its surface to the commutator.

The modern type of dynamo-electric machine is almost always iron-clad. An iron-clad armature gives better mechanical support to its conductors, and is in every respect stronger than an armature of the smooth-cored type, in which the conductors are carried over the surface instead of being imbedded in slots. Moreover, the magnetic pull upon the armature of a dynamo-electric machine is exerted upon the conductors when these lie on the surface of the core as in smooth-core armatures ; but it is exerted almost entirely upon the iron teeth when the conductors are buried in slots, as in iron clad or tooth-cored armatures. Consequently, smooth-cored armatures, are not only structurally weaker than tooth-cored

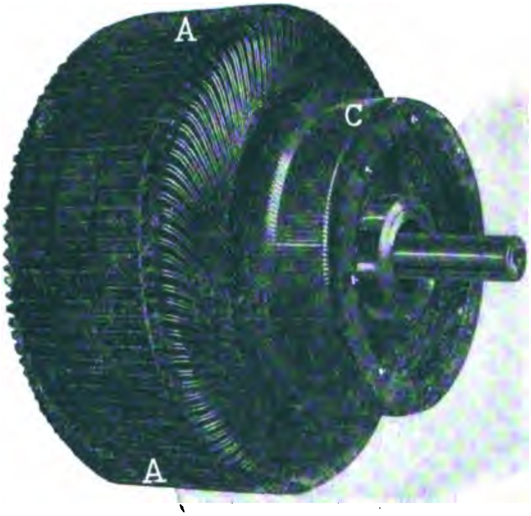


Fig. 31—Armature of Crocker-Wheeler Direct-Connected 100 K. W. Generator.

armatures, but are also more liable to be mechanically injured by unduly powerful magnetic forces. The process of winding an iron-clad armature of this size with wire conductors is represented in Fig. 32.

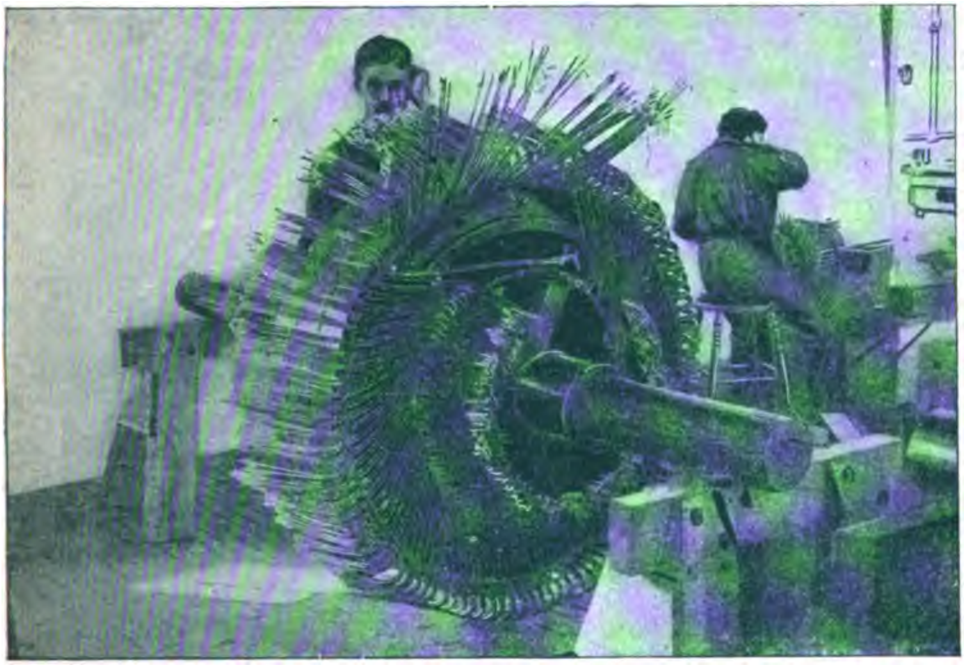


Fig. 32—Crocker-Wheeler Direct-Connected Type Armature Core, Partially Wound.

A 50 K.W. Crocker-Wheeler Electric Company's multipolar generator is shown in Fig. 33, direct-connected to an 80 H. P. Ames horizontal engine, running at 275 revolutions per minute. There are six pairs of metallic brushes resting on the commutator. The brush-holders are supported each from one of a pair of conducting rings alternately. The handle *h*, lifts all the brushes simultaneously. The wheel handle *W*, rotates the brush-holder rings together, so as to adjust the lead of the brushes on the commutator.

Fig. 34, shows a front elevation and axial section of a Crocker-Wheeler, size 280 octopolar generator, two of which are installed at the Columbia University, New York. Its weight is about 43,000 lbs., the output being 200 K. W. at 100 revolutions per minute, or 300 K. W. at 150 revolutions per minute. The external diameter of the cast iron field ring is 107 inches. The cross-section indicates the method of supporting the laminated armature core, with its two ventilating spaces, the method of winding the armature wire in the grooves, and the flange-rings which protect the winding externally. The means adopted for mounting the commutator on the shaft and clamping its segments on the shell are also readily observed.

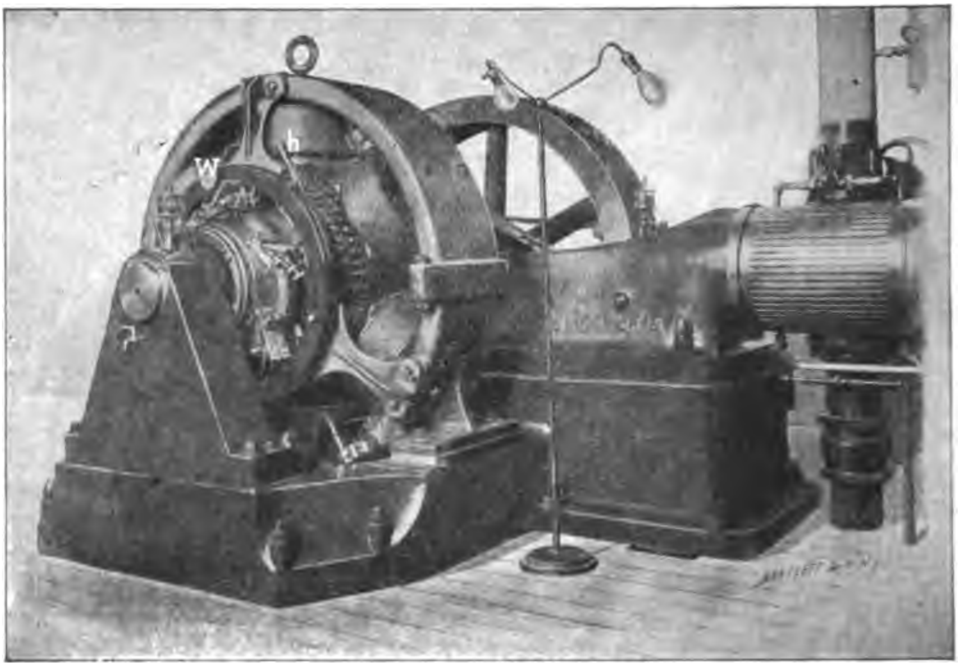


Fig. 33—Crocker-Wheeler 50 K. W. Generator, Directly Connected to Shaft of 80 H.P. Ames Engine.

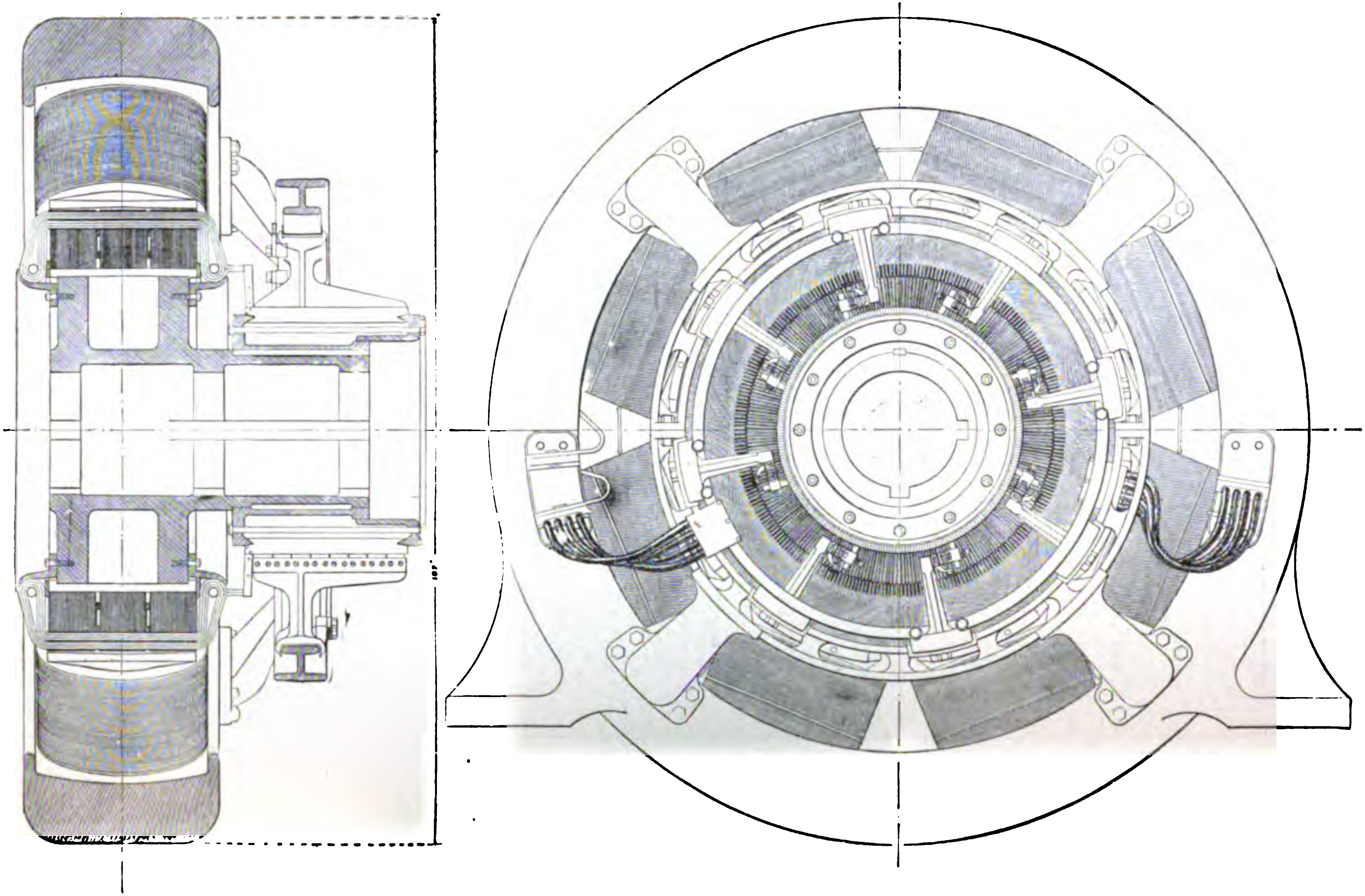


Fig. 34—Front and Side Elevation Drawing, Size 280 Crocker-Wheeler Dynamo.

A 40 H. P. armature in course of being wound is shown in Fig. 35. Channels of micanite like those shown on the armature at cc, are laid in grooves of cardboard and mica, and the wire is wound in them. The armature shown is of the quadripolar, four-circuit ring type, so that the wire is carried through the centre at each turn. The shaft is protected by cloth or canvas to prevent the wires from being abraded by coming in contact with it.

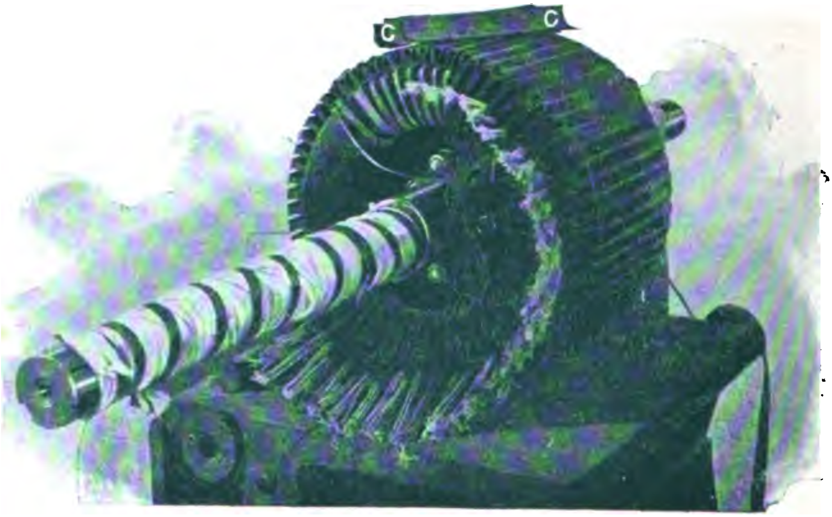


Fig. 35—Crocker-Wheeler Armature Partly Wound.

Fig. 36, shows a Crocker-Wheeler Electric Company's No. 15 dynamo, directly connected to a Case engine. The output is 8 K.W. at 650 revolutions per minute, and the total weight 2300 lbs. Both engine and generator are mounted on a common but independent bed-plate. They are united by a flange coupling. This generator is of the quadripolar type. It is compound wound and has four sets of carbon brushes, which press in a radial direction upon the commutator. T, T, are the main terminals.

We have hitherto described only multipolar direct-connected generators as suitable for isolated service. Modern large generators are always multipolar for the reason that a greater output can be obtained per pound of material, and for a given floor space, with generators of the multipolar type, than with those of the bipolar type, since the magnetic circuit, being divided into a number of symmetrical streams, is more compact.

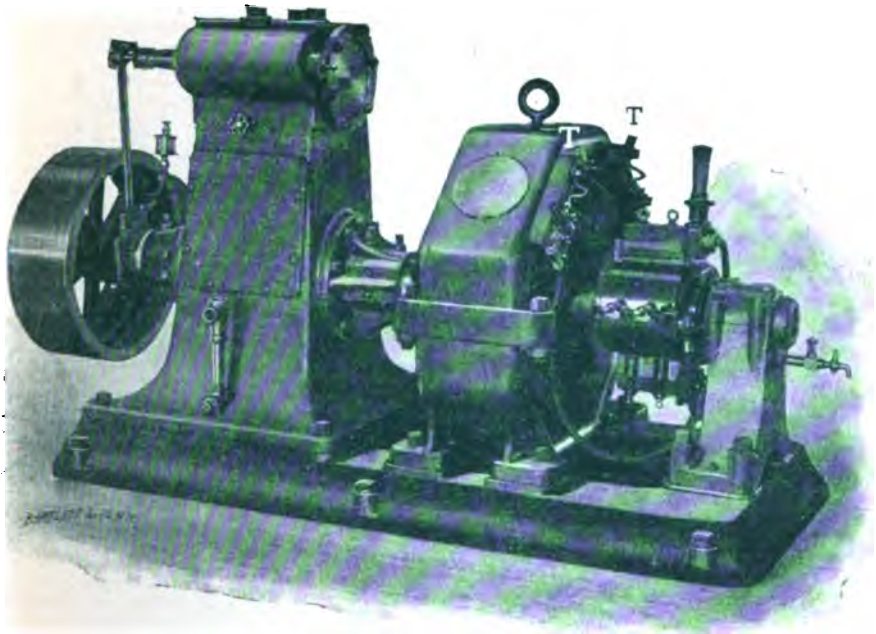


Fig. 36—Crocker-Wheeler Dynamo Directly Connected to Case Engine.

Fig. 37, shows a small direct-driven Crocker-Wheeler Company's bipolar generator connected to a Case engine. Here the machine has two poles N and S, and between them is driven the armature mounted on the engine shaft. There are two pairs of carbon brushes B, B, carried by the rocker arm moved by the handle H. L, is the head-board of the machine carrying the main terminals. The machine shown has an output of 4 K. W., and runs at 650 revolutions per minute, weighing with the engine 1450 pounds. The two machines have a common base plate.

Fig. 38 represents a No. 3, Crocker-Wheeler Electric

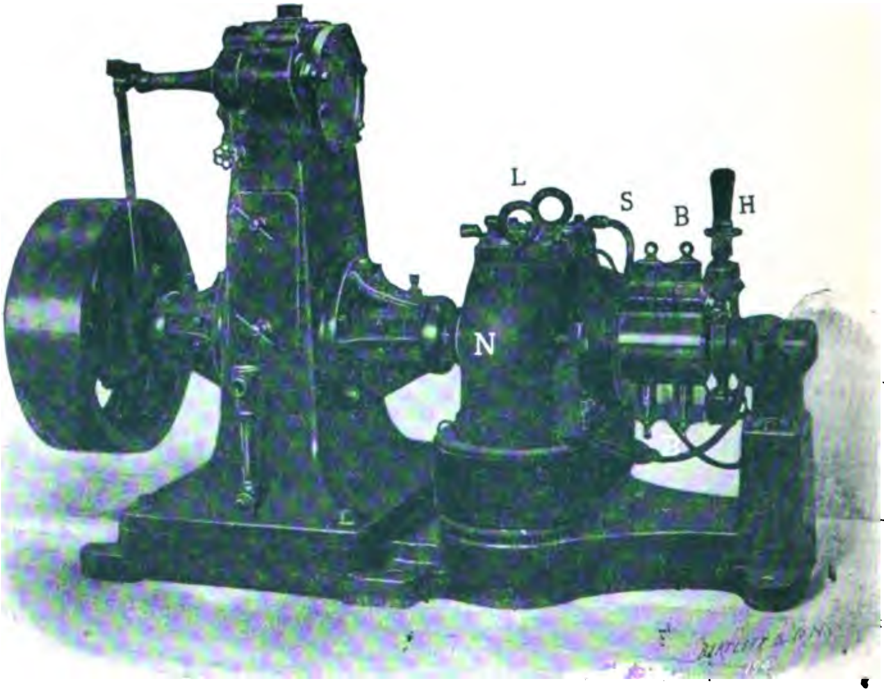


Fig. 37—Crocker-Wheeler Direct-Connected Generator.

Company's bipolar generator, directly connected to a vertical Case engine. This generator has an output of 2 kilowatts, at the speed of 800 revolutions per minute, corresponding to 18.18 amperes at 110 volts pressure. The generator is of the vertical type, having wrought-iron magnet cores with pole pieces, set into a cast-iron base-plate. The commutator has two pairs of metallic brushes. The bearings are self-oiling and the engine runs in oil. A main-circuit switch S, is placed on the head-board, with the main terminals t, t. The engine shaft is extended so as to receive the armature on a keyway.

Fig. 39, shows a Lundell dynamo, directly connected to a Sturtevant engine. This is a quadripolar generator with two sets of brushes. Fig. 40, taken in connection with the accompanying table, shows the dimensions of a small plant of this character with the engine fly-wheel towards the dynamo, and also with the fly-wheel away from the dynamo, to suit local conditions.

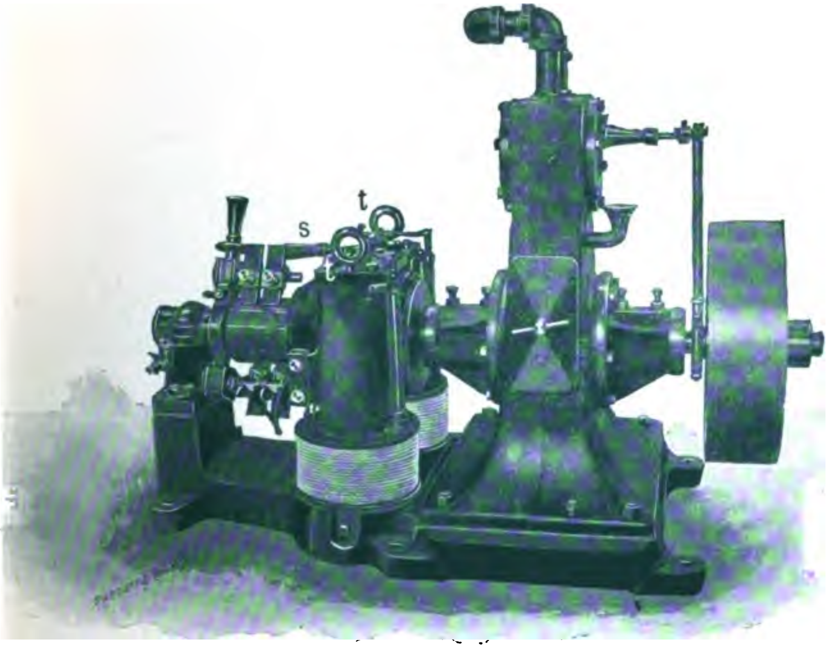


Fig. 38—Crocker-Wheeler Bipolar Generator Connected to a Vertical Case Engine.

TABLE OF DATA OF INTERIOR CONDUIT AND INSULATION CO.'S LUNDELL DIRECT-CONNECTED GENERATOR SETS.

Catalogue Number.	Size of Engine.	H. P. at 80 lbs.	Revs. p. min.	OUTPUT OF DYNAMO. K.W.	Volts Amp.	Volts Amp.	Lights.	Total Weight.	Steam Pipe.	Exh. Pipe.
S 7	$3\frac{1}{2}\times2\frac{1}{2}$	7.0	700	4.0	85 × 47	115× 35	70	1400	$1\frac{1}{2}$	$1\frac{1}{2}$
S 11	4 ×3	10.5	700	6.6	85 × 78	115× 57	114	2000	2	2
S 19	5 ×4	18.8	600	11.0	85 ×129	115× 95	190	3400	2	$2\frac{1}{2}$
S 32	6 ×5	31.0	550	18.5	85 ×218	115×160	320	5800	$2\frac{1}{2}$	3

TABLE OF DIMENSIONS.

Size of Eng.	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R
$3\frac{1}{2}\times2\frac{1}{2}$	$18\frac{1}{8}$	$20\frac{1}{4}$	$15\frac{1}{2}$	$7\frac{11}{16}$	$23\frac{3}{8}$	$13\frac{1}{4}$	$3\frac{3}{8}$	$13\frac{1}{4}$	$48\frac{1}{16}$	$3\frac{3}{4}$	$13\frac{1}{2}$	$6\frac{1}{2}$	$12\frac{5}{16}$	$16\frac{1}{4}$	$5\frac{1}{2}$	20	$24\frac{1}{2}$
4 ×3	$19\frac{1}{4}$	22	17	$9\frac{1}{8}$	$28\frac{3}{16}$	$15\frac{3}{16}$	$3\frac{1}{2}$	$13\frac{3}{4}$	56	$4\frac{1}{2}$	$15\frac{1}{2}$	$6\frac{1}{2}$	$14\frac{11}{16}$	$19\frac{1}{16}$	$6\frac{1}{2}$	24	$29\frac{5}{16}$
5 ×4	21	26	19	$10\frac{1}{8}$	$33\frac{3}{8}$	$19\frac{9}{16}$	4	$15\frac{1}{4}$	$67\frac{1}{16}$	$6\frac{1}{8}$	20	$9\frac{1}{2}$	$16\frac{1}{8}$	$20\frac{13}{16}$	$7\frac{1}{2}$	28	$34\frac{1}{8}$
6 ×5	$23\frac{1}{2}$	$30\frac{1}{2}$	23	$12\frac{11}{16}$	$37\frac{3}{16}$	$23\frac{3}{4}$	$4\frac{1}{2}$	$18\frac{1}{4}$	$78\frac{1}{8}$	$7\frac{3}{16}$	$24\frac{1}{2}$	$10\frac{1}{2}$	$19\frac{5}{16}$	$24\frac{9}{16}$	$8\frac{1}{2}$	32	44

The dimensions of the Lundell dynamos separately, are given in the accompanying table.

DATA OF LUNDELL BELT-DRIVEN DYNAMOS AND MOTORS.

Guaranteed Brake H.-P.	Watts	Amperes at 115 Volts	Voltage	Approximate Speed as Dynamo	PULLEY Diameter	Face	Approximate Speed as Motors
$\frac{1}{16}$	....	....	4 Battery	1900	1	V	1300
$\frac{1}{12}$	....	....	115	1900	1	V	1050
$\frac{1}{8}$	....	..	8 Battery	1800	$1\frac{1}{2}$	V	1200
$\frac{1}{6}$	....	....	115	1800	$1\frac{1}{2}$	V	1200
$\frac{1}{4}$	250	2.2	115,230,500	1700	$2\frac{3}{4}$	$1\frac{1}{2}$	1640
$\frac{1}{2}$	500	4.3	115,230,500	1500	$3\frac{1}{2}$	2	1485
1	1000	8.7	115,230,500	1500	$4\frac{1}{2}$	$2\frac{3}{4}$	1225
2	1920	16.7	115,230,500	1100	6	$3\frac{3}{8}$	1045
3	2750	23.9	115,230,500	1250	6	$3\frac{3}{8}$	1480
4	3675	32.	115,230,500	1200	7	$3\frac{3}{4}$	1150
**5	4525	39.4	115,230,500	1100	8	$4\frac{1}{2}$	1073
**$7\frac{1}{2}$	6650	57.8	115,230,500	1050	9	5	1060
**10	8750	76.1	115,230,500	1000	11	6	878
**15	12700	118.7	115,230,500	1025	13	$6\frac{1}{2}$	785
**20	16700	145.2	115,230,500	800	15	7	725
**25	20650	179.5	115,230,500	750	17	8	770
**35	28500	248.7	115,230,500	800	22	10	750

** 4-pole type, all smaller sizes 2-pole type.

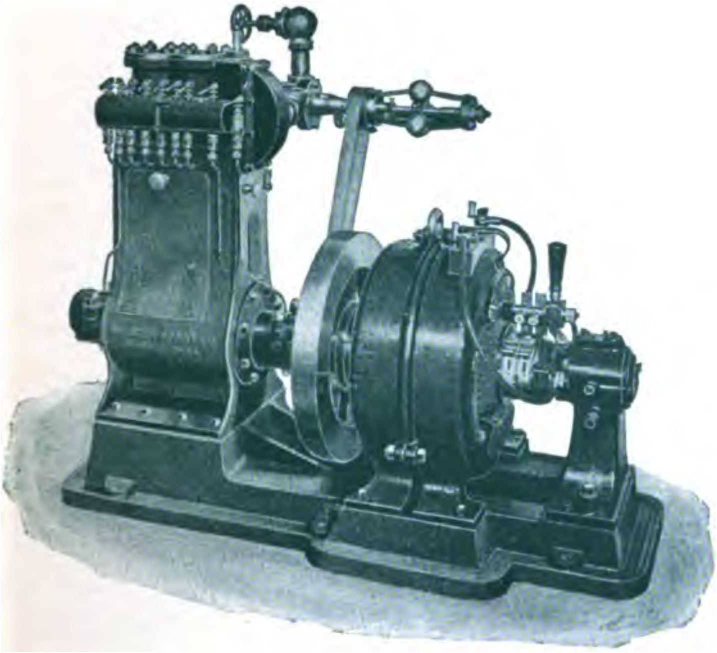


Fig. 39—"Lundell" Dynamo Directly Driven by Sturtevant Engine.

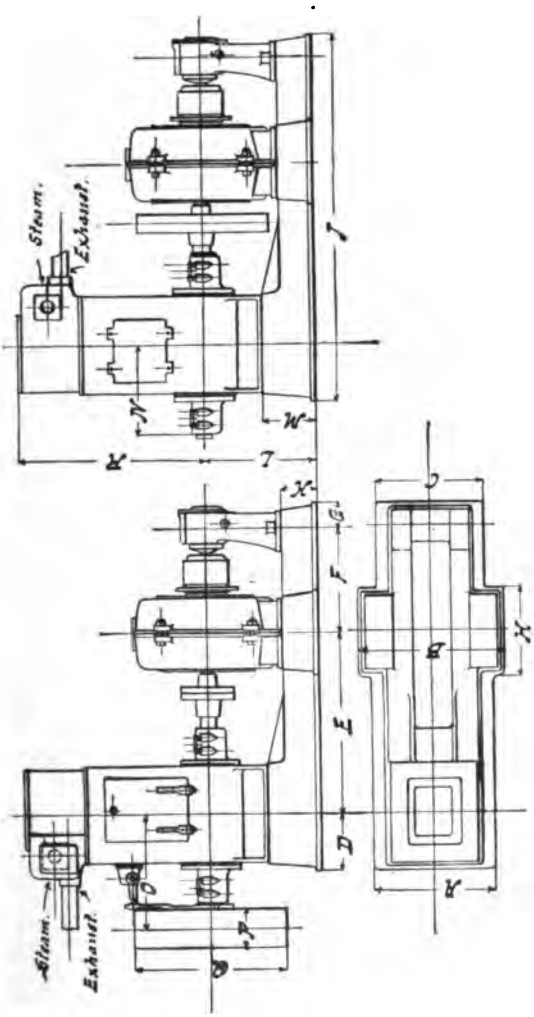


Fig. 40—Dimensions of "Lundell" Dynamo Directly Driven by Sturtevant Engine.

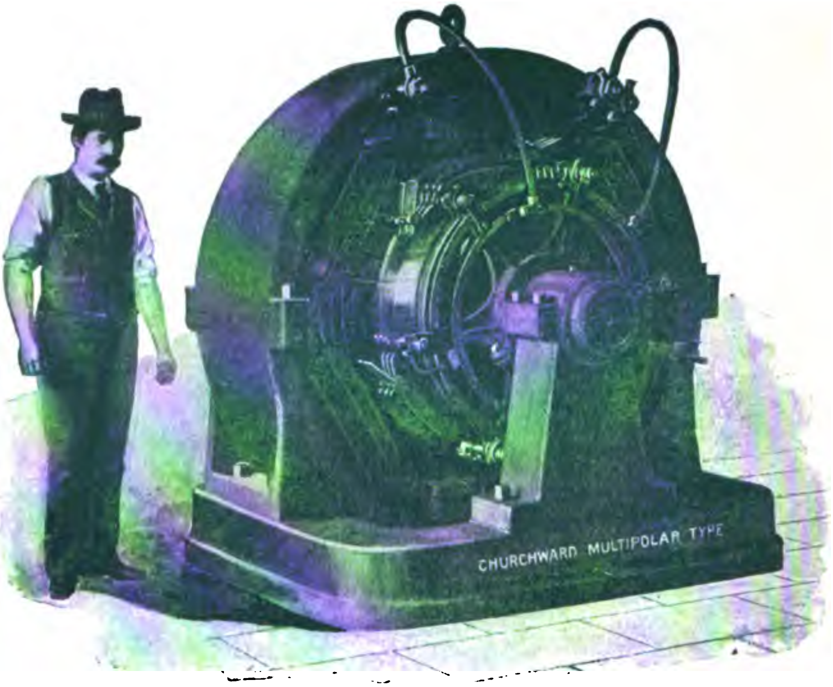
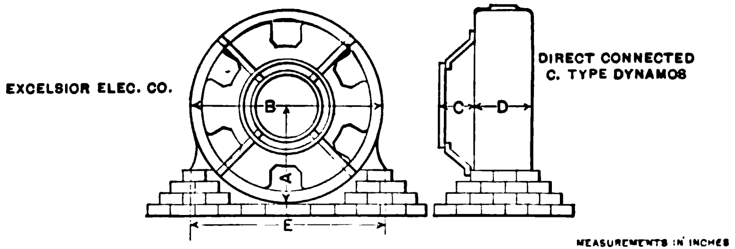


Fig. 41—"Excelsior" 150-Kilowatt Direct-Connected Generator.



MEASUREMENTS IN INCHES

NO.	VOLTS	AMP.	K. W.	SPEED	A	B	C	D	E	F	DIAM. OF SHAFT
19			25	300	22	44	12	16	44		4
20			50	300	25½	51¾	14	16	50½		5
21			75	300	25½	51¼	14	20	50½		6
22			100	250	34½	69	15	20	67		6
23			150	250	34½	69	16	24	67		7
24			200	225							
25			300	200							

Bartlett & Co., N.Y.

Fig. 42—Dimensions of "Excelsior" Direct-Connected Generators.

Fig. 41, represents an Excelsior Electric Company's 150 kilowatt direct-connected generator. This is a sextipolar machine with six sets of metallic brushes. The dimensions of these machines are indicated in the accompanying table in connection with Fig. 42.

Nearly all isolated-plant generators are compound-wound ; that is to say, their field-magnets have two windings, one of which is connected across the terminals of the machine, and the other is in the armature circuit.

This is diagrammatically represented in Fig. 43, where a compound-wound bipolar-machine is indicated on the left hand side, and a compound-wound quadripolar-machine on the right hand side.

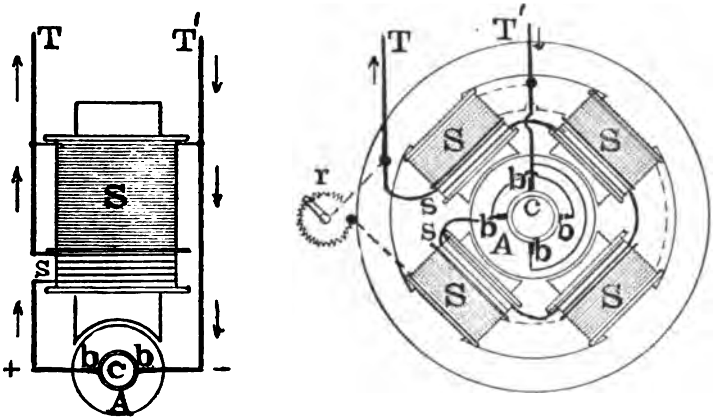


Fig. 43—Diagram of Compound Winding.

The armature A, is connected to the main terminals T, T', through a small number of turns s, of coarse wire on the field magnet or magnets. This coarse winding is called the *series winding*, since it is in series with the armature. The larger magnetizing coil S, is of fine wire, and is connected in shunt to the circuit, or between the terminals T,T'. It is therefore called a *shunt-winding*. A *shunt-wound machine* has no series winding. A *series-wound machine* has no shunt-winding ; while a *compound-wound machine* has both series and shunt-winding. The purpose of the series-winding in a compound-wound machine is to strengthen the magnets by the current supplied from the armature to the circuit, and, therefore, automatically to sustain the pressure.

In the absence of the coarse winding, the pressure at the dynamo terminals would tend to fall as the load increased. This tendency to fall is counteracted by the excitation of the series, or coarse-winding, which, increasing with the load, tends to make the pressure rise. The coarse and fine windings are so adjusted, in regard to the number of turns and their relative current strengths, that the pressure at the machine terminals is maintained practically constant under all loads. In some cases it is desirable to have the pressure actually rise under load, say five per cent, in order to compensate for the drop of pressure which may occur in the main conductors. In such a case the machine is said to be *over-compounded.*

The compound winding of the generators already referred to will be evident on an inspection of Figs. 20 and 29.

With very small direct-driven generators, where the engine and dynamo are mounted on the same bed-plate, but little attention is required for the foundation, a good solid floor being sufficient. The larger and heavier the dynamo, however, the greater the necessity for obtaining a firm foundation. As a rule, direct-driven generators, of over 10 K. W. capacity, should be placed in a basement floor on a brick or concrete foundation resting directly on the ground. It is always advisable to lay the foundation for the generator and its driving engine at the same time so that they may set together.

In setting up a direct-driven generator, care should be taken in placing the armature on the engine shaft to prevent its being injured by scraping against the field poles.

In operating a direct-driven generator, attention should be given to the brushes and to the bearings. Any want of alignment in the outside bearing is apt to produce heat in one or both bearings of the machine. The brushes should press uniformly upon the commutator, and should be so set that their friction is distributed as nearly uniformly as possible over the length of the commutator segments.

When a generator is started into operation, it is first brought up to full speed. Its field circuit is then closed, and all the resistance turned out at the ***shunt-field rheostat*** r, Fig. 43, so that as powerful a magnetizing current as possible may pass round the shunt coil of the magnets. The voltage generated by the machine is then watched as it rises, at the voltmeter, and the field rheostat is then adjusted until the correct pressure is maintained. The main switch is then closed.

CHAPTER III.

BELT-DRIVEN CONTINUOUS-CURRENT GENERATORS FOR ISOLATED PLANTS.

WHERE low first cost is a matter of principal importance, and where the use of belts is no disadvantage, belt-driven generators are preferably employed for isolated service. They have the advantage that they can be installed wherever an engine has already been located with reserve power. It is only necessary in such cases to provide the requisite belting, a foundation and floor space for the dynamo, and, in some cases, an intermediate counter-shaft for obtaining the necessary belt speed.

For very small generators, gas or oil engines are sometimes suitable. These engines usually deliver but one impulse to their pistons in every two revolutions of their main shaft. Consequently, at every such impulse the speed is accelerated to a degree that becomes very noticeable in the steadiness of the light of the incandescent lamps that may be operated from the dynamo driven by the engine. A large fly-wheel for the dynamo is, therefore, necessary, unless the engine is already provided with a large fly-wheel, in order to maintain the speed as nearly constant as possible. A form of Lundell dynamo, provided with a fly-wheel and pulley for belt-connection with a gas engine, is shown in Fig. 44. The generator which is quadripolar, does not differ from that shown in Fig. 39. The weights and dimensions of these dynamos are given in the accompanying table.

It will be observed that these dynamos are constructed up to an output of 28 1-2 K. W.

The General Electric Company's type of small bipolar generator, suitable for isolated service, occupying small floor

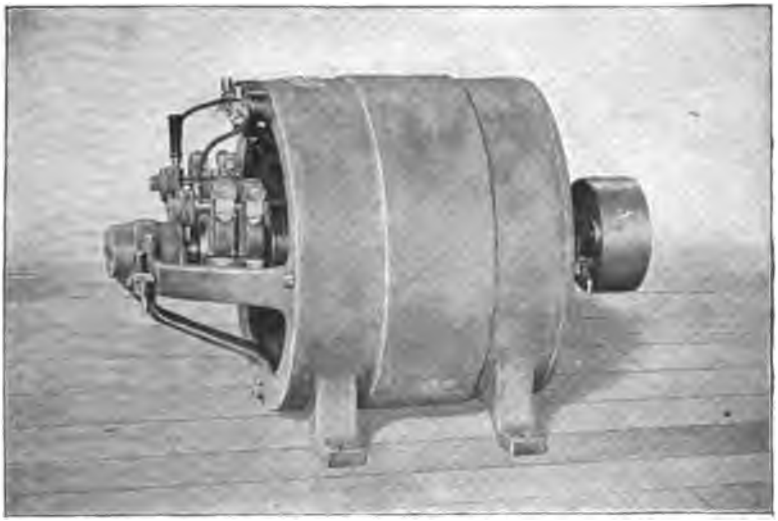


Fig. 45—" General Electric " Belt-Driven Ironclad Bipolar Generator.

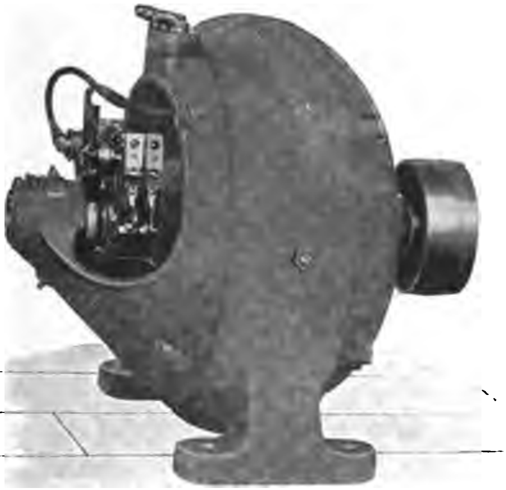


Fig. 46—" General Electric " Belt-Driven Ironclad Bipolar Generator.

space, and called the iron-clad bipolar, (I B), generator, is shown in Fig. 45. In this machine the field frame completely surrounds the armature, so that the machine is well protected from mechanical injury. A later type of this machine is

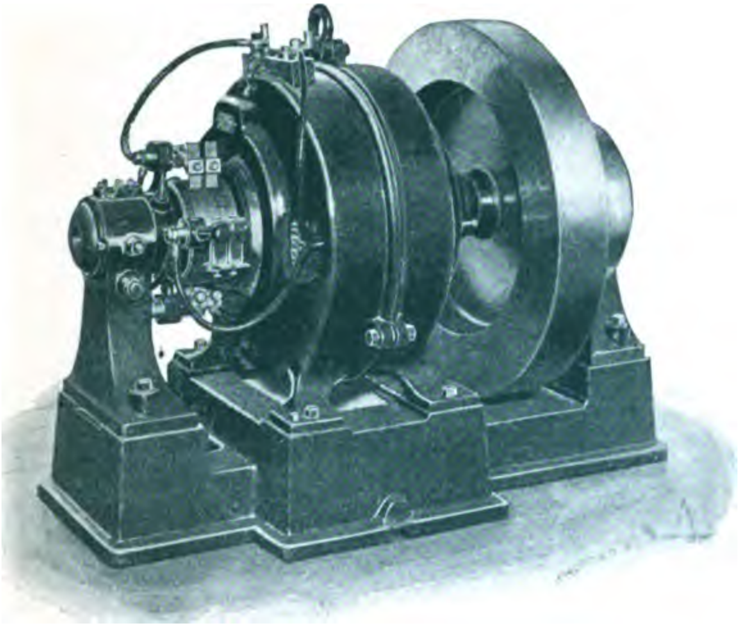


Fig. 44—Lundell Generator for Gas Engine Service.

Indicated H.-P. of Eng.	Amperes at 115 Volts.	16-candle-power Lights.	Kilowatts	Voltage.	Approximate Speed.
8.	40	77	4.53	115 to 150	1100
11.5	58	113	6.65	115 to 150	1050
15.	76	148	8.75	115 to 150	1000
21.	111	216	12.75	115 to 150	900
27.5	145	284	16.70	115 to 150	850
33.5	180	351	20.65	115 to 150	750
45.5	250	484	28.50	115 to 150	650

shown in Fig. 46. These generators are wound for standard voltages of 125, 250 or 500 volts. The 125-volt machines are suitable for two-wire incandescent lighting, where but a single pair of mains with branches is employed, say in a building. 250-volt machines are suitable for the distribution of power by 220-volt motors. The 500-volt generators are suitable for 500-volt motor distribution. In all dynamo machines a 250-volt armature has, approximately, twice as many turns of half cross section, and a 500-volt armature has, approximately, four times as many turns of quarter cross section, as a 125-volt armature of the same capacity. The same field frame is employed for all these voltages, but

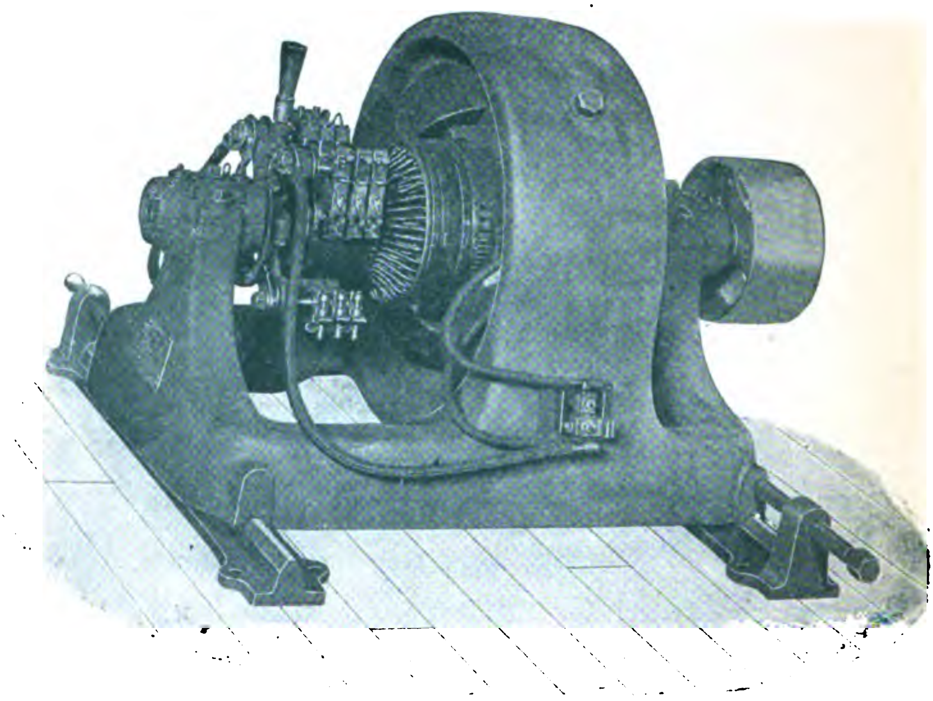


Fig. 47—"General Electric" Company's Belt-Driven Generator.

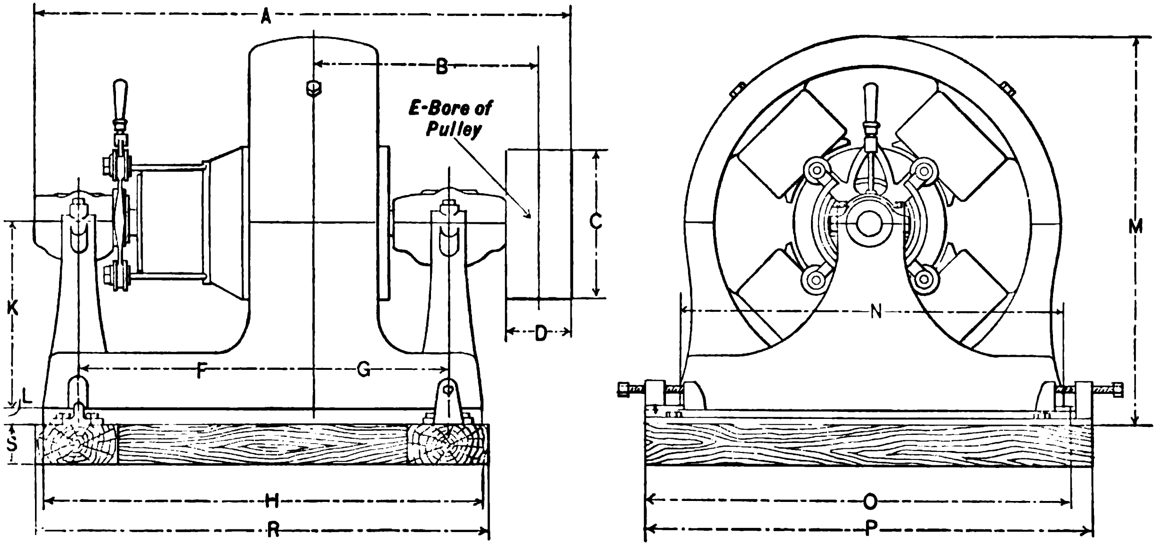


Fig. 47A—Dimensions of General Electric Company's Belt-Driven Moderate Speed and Slow-Speed Generator.

TABLE OF GENERAL ELECTRIC COMPANY'S MODERATE SPEED BELT-DRIVEN GENERATORS.

CLASSIFICATION.					WEIGHT.														RAILS—O.		WOOD BASE FRAME.				KEYWAY.
Type.	Poles.	K. W.	Speed.	Form.	With Rails.	Without Rails.	A	B	C	D	E	F	G	H	K	L	M	N	Length.	Symbol.	P	R	S	Symbol.	
MP	4	9	1450	H	1,035	970	38 3/16	16 1/8	8 1/2	4 3/4	1 3/8	16 1/2	10 3/4	31 3/4	12	1 3/8	25 3/8	26	34 3/4	AD 17	36 1/8	34 1/4	3	CH 42	3 " x 3/8" x 3/16"
MP	4	12.5	1350	H	1,460	1,370	42 5/8	18 3/8	10	6 1/2	1 3/4	17 1/4	11 3/4	34 1/2	13 7/8	1 1/2	29 1/4	30	39	AD 18	40 1/4	36	3	CH 44	3 3/4 " x 1/2" x 1/4 "
MP	4	17.5	1175	H	1,955	1,860	49 5/8	21 3/8	11 1/2	8 3/4	2	19 7/8	13 1/8	39	15 1/2	1 1/2	32 1/4	33	43 1/2	AD 19	43 1/2	40	3	CH 45	5 3/4 " x 1/2" x 1/4 "
MP	4	25	1100	H	2,610	2,500	56 7/8	25	12 1/2	9	2 1/8	22 1/4	15 1/4	44 1/4	16 3/4	1 1/2	35	36	44 1/2	AD 20	46 1/4	44 1/4	3	CH 46	6 1/16" x 1/2" x 1/4 "
MP	4	30	1050	H	4,110	3,960	60 3/4	26 3/4	13	11	2 1/4	22 3/4	15 3/4	45 1/2	18 1/2	1 5/8	38 3/8	40	52	AD 21	53	48 1/2	4	CH 47	6 1/8 " x 1/2" x 1/4 "
MP	4	45	975	H	5,080	4,920	68 3/4	29 7/8	16 3/4	13	2 3/4	26 3/8	18 3/8	52 3/4	22 1/2	1 5/8	46 1/8	46 1/2	55	AD 22	58 3/4	54 3/4	4	CH 48	8 " x 5/8" x 5/16"
MP	4	55	925	H	7,325	6,150	72 1/2	32 1/8	17 3/4	16 3/4	3 1/8	25 7/8	18 1/2	52 7/8	24	1 5/8	49	50 3/4	60 1/2	AD 23	63	54 3/8	6	CH 49	11 " x 3/4" x 3/8 "
MP	4	65	875	H	7,410	7,200	79 1/8	33 1/8	18 3/4	19 1/2	3 1/4	29 3/4	18 7/8	57 5/8	25	1 3/4	51 3/4	53	62 3/4	AD 24	65 3/4	58 5/8	6	CH 50	12 1/4 " x 3/4" x 3/8 "
MP	4	85	750	H	8,435	8,190	91 3/4	39	21 3/4	24	3 7/8	34 1/4	19 3/4	63 1/2	27	2	56	56 1/2	65 1/2	AD 26	68 1/4	64	6	CH 51	16 1/4 " x 1 " x 1/2 "

TABLE OF GENERAL ELECTRIC COMPANY'S SLOW-SPEED BELT-DRIVEN GENERATORS.

Type.	Poles.	K. W.	Speed.	Form.	With Rails.	Without Rails.	A	B	C	D	E	F	G	H	K	L	M	N	Length.	Symbol.	P	R	S	Symbol.	Keyway.
MP	4	6.5	950	H	1,035	970	37 15/16	16 1/8	11	4 1/4	1 3/8	16 1/2	10 3/4	31 3/4	12	1 3/8	25 3/8	26	34 3/4	AD 17	36 1/8	34 1/4	3	CH 42	3 " x 3/8" x 3/16"
MP	4	9	900	H	1,460	1,370	42 5/8	18 3/8	11 1/2	6 1/2	1 3/4	17 1/4	11 3/4	34 1/2	13 7/8	1 1/2	29 1/4	30	39	AD 18	40 1/4	36	3	CH 44	3 3/4 " x 1/2" x 1/4 "
MP	4	13.5	850	H	1,955	1,860	49 1/2	21 3/8	12 1/4	8 1/2	2	19 7/8	13 1/8	39	15 1/2	1 1/2	32 1/2	33	43 1/2	AD 19	43 1/2	40	3	CH 45	5 3/4 " x 1/2 x 1/4 "
MP	4	17	750	H	2,610	2,500	56 5/8	25	13 3/4	8 1/2	2 1/8	22 1/4	15 1/4	44 1/4	16 3/4	1 1/2	35	36	44 1/2	AD 20	46 1/4	44 1/4	3	CH 46	6 1/16" x 1/2" x 1/4 "
MP	4	20	700	H	4,110	3,960	60 1/2	26 3/4	15	10 1/2	2 1/4	22 3/4	15 3/4	45 1/2	18 1/2	1 5/8	38 3/8	40	52	AD 21	53	48 1/2	4	CH 47	6 1/8 " x 1/2" x 1/4 "
MP	4	30	675	H	5,080	4,920	67 3/4	29 7/8	20 1/2	11	2 3/4	26 3/8	18 3/8	52 3/4	22 1/2	1 5/8	46 1/8	46 1/2	55	AD 22	58 3/4	54 3/4	4	CH 48	8 " x 5/8 x 5/16"
MP	4	40	605	H	7,325	6,150	71 7/8	32 1/8	22 3/4	15 1/2	3 1/8	25 7/8	18 1/2	52 7/8	24	1 5/8	49	50 3/4	60 1/2	AD 23	63	54 3/4	6	CH 49	11 " x 3/4" x 3/8 "
MP	4	50	600	H	7,410	7,200	78 5/8	33 1/8	23	18 1/2	3 1/4	29 3/4	18 7/8	57 5/8	25	1 3/4	51 3/4	53	62 3/4	AD 24	65 3/4	58 5/8	6	CH 50	12 1/4 " x 3/4" x 3/8 "
MP	4	75	550	H	8,435	8,190	92	39	25	24 1/2	3 7/8	34 1/4	19 3/4	63 1/2	27	2	56	56	65 1/2	AD 26	68 1/4	64	6	CH 51	16 1/4 " x 1 " x 1/2 "

the winding differs both in the field magnets and in the armature.

The General Electric Company's standard belt-driven generator is illustrated in Fig. 47. These machines are quadripolar up to 85 K. W. capacity, and are constructed in two classes, namely, *moderate-speed* generators, and *slow-speed* generators. As we have already seen, the output of a generator of given size and weight is increased if designed for an increased speed. Thus, a 9 K. W. generator of the moderate-speed class weighs 970 lbs., and runs at 1450 revolutions per minute. A 9 K. W generator of the slow-speed class weighs 1370 lbs., and runs at 900 revolutions per minute. It will therefore be observed that in this case the reduction in speed of 38% is obtained by an increase in weight of 41%. The particulars concerning these two classes of generators are given in the accompanying tables with reference to Fig. 47 A.

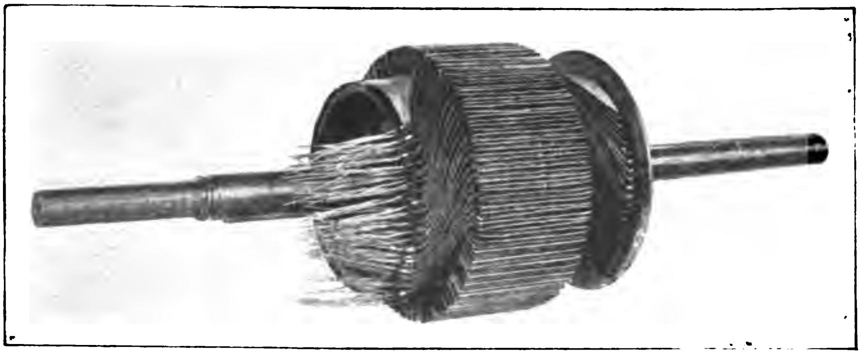


Fig. 48—Incomplete Armature Core and Coils for "General Electric" Belt-Driven Armature.

The frames of these machines are of cast-iron, with pole-pieces of soft steel. They have, iron-clad, ventilated armatures. Fig. 48, shows the incomplete armature for one of these machines, while Fig. 49, shows a completed armature. Carbon brushes are employed.

Fig. 50, represents a Wood Belt-Driven Multipolar Dynamo for 75 K.W., or about 100 electric horse-power, at 275 revolutions, suitable for isolated service. There are six sets of metal brushes corresponding to the six poles. These brushes are held in a star frame, which is rotated by the wheel handle W, situated below the main bearing of the machine. The current is carried from the main terminals T, T, which are mounted on slate blocks in the pedestal. The small terminals t, t, are for connection to the shunt-field rheostat, by which the pressure at the terminals of the machine is controlled. The connections of the machine start from the centre of the pedestal and are accessible through the grate door D. The accompanying table gives the dimensions of these machines.

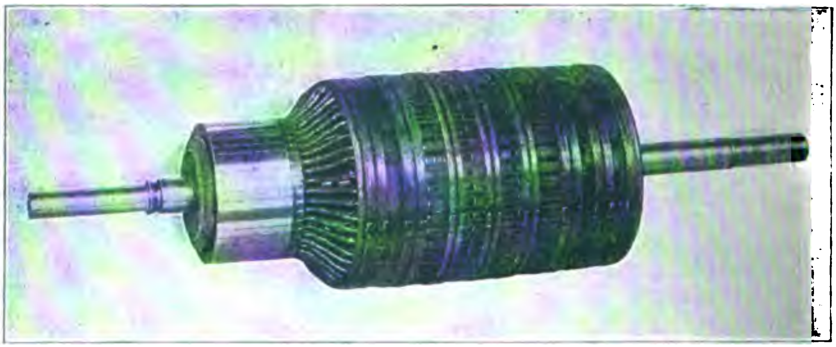


Fig. 49—Armature of "General Electric" Belt-Driven Generator.

It is interesting to observe in connection with the above table the difference in weight of a belt-driven and direct-driven machine of the same power, owing to their difference in speed. Thus a 25 K. W. direct-driven armature, running at 300 revs. per minute, weighs only about 13% less than a 50 K. W. belt-driven armature, running at 600 revs. per minute.

Fig. 51, shows a Westinghouse Electric and Manufacturing Company's type of belt-driven generator, suitable for isolated service. These machines are quadripolar, with round field-frames. They have laminated steel pole-pieces,

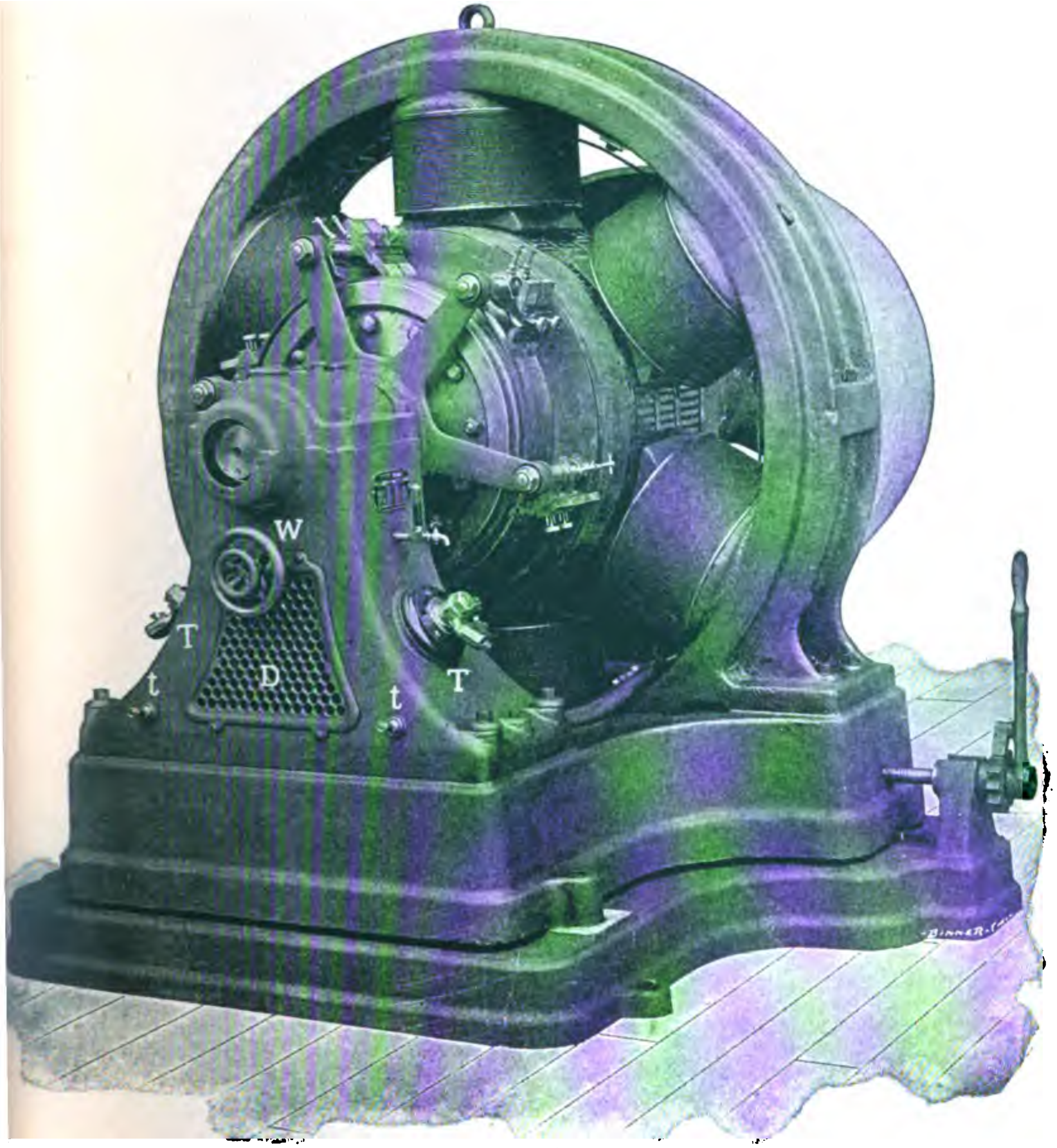


Fig. 50—"Wood" 75 Kilowatts Belt-Driven Generator.

TABLE OF WOOD CONTINUOUS-CURRENT STEEL MULTIPOLAR GENERATORS FOR DIRECT CONNECTION OR BELT-DRIVING, COMPOUND-WOUND FOR 125, 250 and 500 VOLTS.

Poles.	Kilowatts.	Revolutions.	Maximum Amps. at 125 Volts.	Horse Power Required.	Diameter of Pulley.	Face of Pulley.	Width of Belt.	Floor Space. First Dimension is Parallel to Shaft.	Total Height.	Weight of Armature.	Weight of Dynamo, Complete.
6	15	375	120	23	Dir	ect	Dri	ven		450	1450
6	30	750	240	45	14	8	7	50 x 53	$42\frac{3}{8}$	540	2300
6	25	300	200	38	Dir	ect	Dri	ven.		900	2600
6	50	600	400	75	20	10	9	$58\frac{3}{16}$ x $63\frac{1}{2}$	$53\frac{1}{8}$	1040	3950
6	50	275	400	75	Dir	ect	Dri	ven.		1150	4500
6	100	550	800	150	28	15	14	$69\frac{9}{16}$ x 74	$62\frac{3}{4}$	1350	7800
6	75	275	600	113	Dir	ect	Dri	ven.		2200	7825
6	150	550	*	225	32	19	18	$81\frac{7}{8}$ x 85	73	2600	12075
6	100	275	800	150	Dir	ect	Dri	ven.		2500	9475
6	200	550	*	300	32	25	24	$92\frac{7}{8}$ x 91	$78\frac{5}{8}$	3100	15300
8	130	250	1080	195	Dir	ect	Dri	ven.		3875	11875
8	260	500	*	390	36	29	28	$103\frac{1}{8}$ x $96\frac{3}{4}$	$83\frac{1}{8}$	4675	18300

* The 150 K.W., 200 K.W. and 260 K.W. machines are built for 230 and 500 volts only.

iron-clad ventilated armatures, and carbon brushes. B_1, B_2, are the conducting bars leading to the series or coarse winding of the field magnets, so that by connecting the external

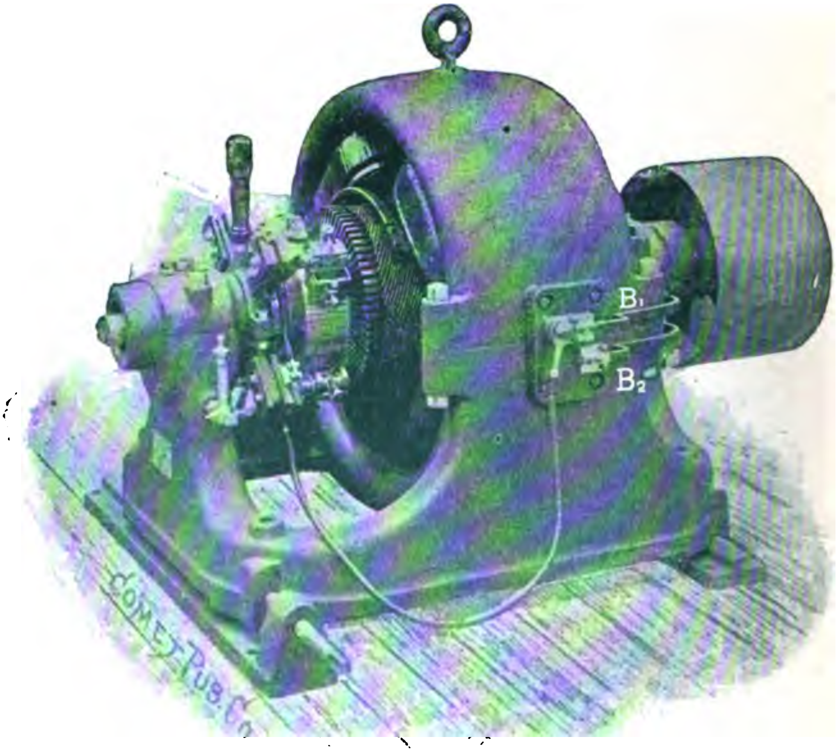


Fig. 51—" Westinghouse " 22 1-2 K. W. Multipolar Generator.

circuit to B_2, the armature current passes through this series winding.

The field rheostats employed with these machines are represented in Fig. 52. The smaller rheostats are cylindrical in form, with ventilated cases of planished iron. For large sizes, in which more heat has to be liberated, a rectangular frame is used, the parts being mounted directly upon a marble face-plate. The amount of resistance which is inserted in the circuit of the shunt-winding on the field-magnets, depends upon the position of the rheostat contact, and by turning the handle to the right or left a greater or less amount of resistance is included in the circuit as shown in Fig. 53, where the total resistance of the coils r, r, etc., is included between the terminals T, T, of the instrument. By turning the handle in a direction opposite to that of the hands of a clock, the resistance in the circuit is diminished. The accompanying table in conjunction with Fig. 54, gives the dimensions and weights

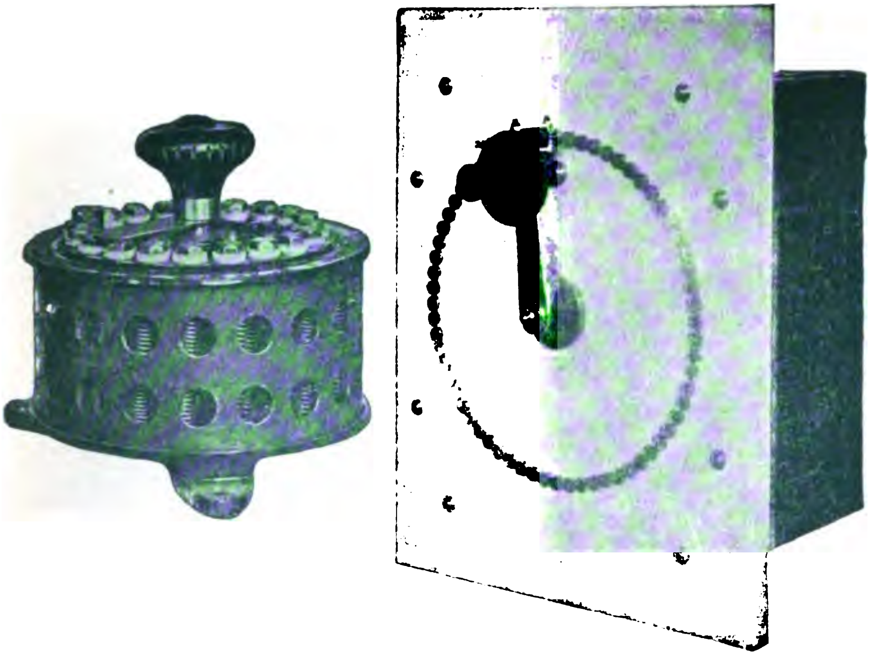


Fig. 52—Field Rheostats for Westinghouse Generators.

of these four-pole machines, up to 56¼ kilowatts output. The first column refers to their use as motors which will be subsequently considered. In sizes of 100 K. W. to 150 K. W. inclusive, six-pole generators are employed.

Large belt-driven Westinghouse generators are usually built with two bearings up to 200 K. W. capacity, and are called *two-bearing* generators. In sizes of 250 K. W. and 500 K. W., they are usually built with three bearings, the additional bearing being between the pulley and the armature. These are called *three-bearing* generators. The principal dimensions of these machines are given in the following tables, that will be understood by reference to Fig 54 which, however, only represents a two-bearing generator.

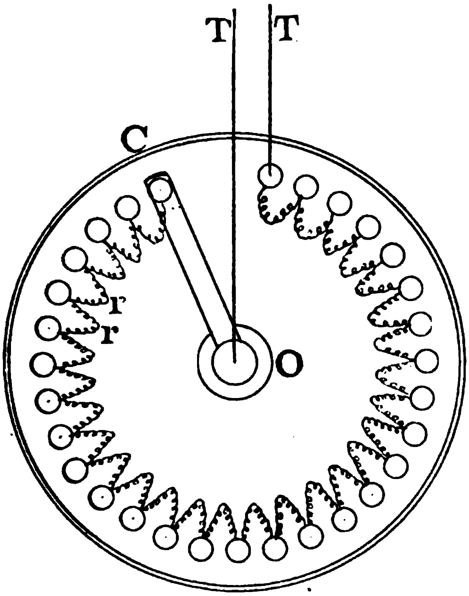


Fig. 53—Diagram of Rheostat Connections.

These machines have field windings in which the series coils are completely separated from the shunt coils, to facili-

TABLE OF WESTINGHOUSE COMPANY'S 4-POLE MACHINES WITH RAILS—APPROXIMATE DIMENSIONS.

Motors.	GENERATORS.				Gen. 125 v.	Motors 110-220 and 500 volts. Generators 250 and 500 volts.	A	D	E	I	M	O	P	Q	PULLEY.			Average Net Weight. Lbs.
					APPROXIMATE.													
HP.	K.W.	Amp. 125 v.	Amp. 250 v.	Amp. 500 v.	Revs.	Revs.									Diam.	Face.	Length of Hub.	
¾	.56	4.5			1400	1300	22	16⅝	15/16	16½	17¾	14⅜	18	23½	3½	2½	2½	190
1	.75	6	3	1.5	2000	1900	22	16⅝	15/16	16½	17¾	14⅜	18	23½	3½	2½	2½	190
2	1.50	12	6	3.	1300	1200	26¼	19⅞	1 3/16	19¼	18¾	15½	19¾	24	5	3	2½	290
2½	1.875	15	7.5	3.7	1800	1700	26¼	19⅞	1 3/16	19¼	18¾	15½	19¾	24	5	3	2½	290
3½	2.62	21	10.5	5.25	1150	1050	32	24⅛	1 7/16	23⅝	22⅞	19	24½	30½	6	4	3½	550
5	3.75	30	15	7.5	1600	1500	32	24⅛	1 7/16	23⅝	22⅞	19	24½	30½	6	4	3½	550
5	3.75	30	15	7.5	1000	950	36	26⅝	1⅝	25¾	24⅜	20¼	25⅝	31¾	8	5	4½	740
7½	5.62	45	22.5	11.25	1400	1350	36	26⅝	1⅝	25¾	24⅜	20¼	25⅝	31¾	8	5	4½	740
7½	5.62	45	22.5	11.25	875	850	38	28¼	1⅝	28⅛	26⅝	22⅜	30⅛	37½	8	5	4½	940
10	7.50	60	30	15	1300	1250	38	28¼	1⅝	28⅛	26⅝	22⅜	30⅛	37½	8	5	4½	940
10	7.50	60	30	15	775	750	40¾	30⅛	1⅞	29⅜	30	25¼	32¾	39¾	9	6	5½	1190
15	11.25	90	45	22.5	1200	1150	40¾	30⅛	1⅞	29⅜	30	25¼	32¾	39¾	9	6	5½	1190
15	11.25	90	45	22.5	700	650	44½	32⅞	1⅞	32⅛	32½	27⅞	34¾	41½	11	8	5½	1550
20	15.	120	60	30	1050	1050	44½	32⅞	1⅞	32⅛	32½	27⅞	34¾	41½	11	8	5½	1550
20	15.	120	60	30	600	600	50½	37⅝	2⅛	37⅜	36⅜	31¾	40½	50½	14	8	6½	2460
30	22.5	180	90	45	975	975	50½	37⅝	2⅛	37⅜	36⅜	31¾	40½	50½	14	8	6½	2460
30	22.5	180	90	45	600	575	56½	42	2⅜	41¼	41½	36½	46½	54½	15	11	7	3410
40	30.	240	120	60	950	950	54½	39⅞	2⅜	39¼	39¼	34½	45	52	15	11	7	2950
40	30.	240	120	60	550	550	65¾	47¼	2⅝	46¼	43⅝	37½	44	55⅜	20	11	8	3900
50	37.5	300	150	75	900	900	56½	42	2⅜	41¼	41½	36⅛	46½	54½	15	11	7	3410
50	37.5	300	150	75	550	550	66	47⅞	2⅝	46¾	43⅞	38¾	46½	55¾	20	11	8	4300
75	45.	360	180	90	850	850	65¾	47¼	2⅝	46¼	43⅝	37½	44	55⅝	20	11	8	3900
60	56.25		225	112.5		800	66	47⅞	2⅝	46¾	43⅞	38¾	46½	55¾	20	11	8	4300

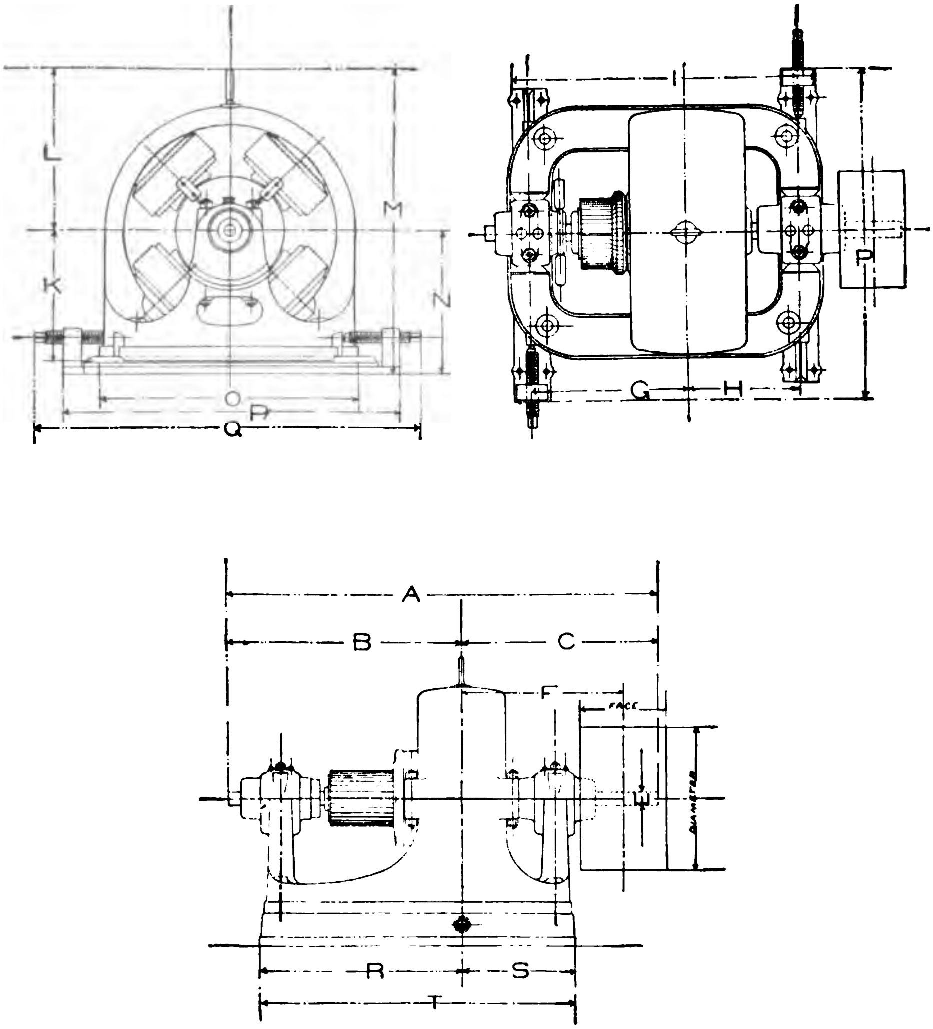


Fig. 54--Westinghouse 4-pole Belt-Driven Generators up to 56.25 K. W. Output.

TABLE OF WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY'S BELT-DRIVEN 6-POLE, 2-BEARING DIRECT-CURRENT RAILWAY GENERATORS.

K.W.	AMP.	R. P. M.	A	B	C	E	F	K	M	N	P	Q	R	S	T	PULLEY.			KEY-WAY IN SHAFT.		Weight Net Lbs.
																Diam.	Face.	Length of Hub.	Width.	Depth.	
100	182	650	85$\frac{3}{16}$″	43$\frac{7}{8}$″	41$\frac{5}{16}$″	3$\frac{7}{8}$″	35$\frac{3}{4}$″	24″	61$\frac{1}{8}$″	30″	61″	67″	34$\frac{5}{8}$″	23$\frac{3}{4}$″	58$\frac{1}{2}$″	28″	18″	10″	$\frac{7}{8}$″	$\frac{3}{8}$″	9,400
150	273	550	96$\frac{1}{4}$″	48$\frac{1}{8}$′	48$\frac{1}{8}$″	4$\frac{3}{4}$″	39″	29″	70$\frac{1}{4}$″	35″	75$\frac{1}{2}$″	81″	38$\frac{3}{4}$″	25$\frac{5}{8}$″	64$\frac{1}{4}$″	34″	26″	16″	1″	$\frac{3}{8}$	14,000
200	364	510	9′ 2″	50$\frac{3}{4}$″	59$\frac{1}{4}$″	5$\frac{7}{8}$″	47$\frac{1}{2}$″	32$\frac{1}{2}$	77$\frac{3}{4}$″	38$\frac{1}{2}$″	82″	87$\frac{1}{2}$″	43$\frac{7}{8}$″	29$\frac{1}{8}$″	73″	35″	33″	20″	1$\frac{9}{16}$″	$\frac{9}{16}$″	19,730

TABLE OF WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY'S BELT-DRIVEN 6-POLE, 3-BEARING DIRECT-CURRENT RAILWAY GENERATORS.

K.W.	AMP.	R. P. M.	A	B	C	E	F	K	M	N	P	R	S	T	PULLEY.			KEY-WAY IN SHAFT.		Weight, Net Lbs.
															Diam.	Face.	Length of Hub.	Width.	Depth.	
250	455	450	12′ 4$\frac{1}{4}$′	54$\frac{3}{4}$	93$\frac{5}{8}$″	6$\frac{1}{2}$″	50$\frac{1}{2}$′	39′	88″	46′	98″	49$\frac{1}{4}$″	88$\frac{1}{4}$″	11′ 5$\frac{1}{2}$	38″	42″	32′	1$\frac{9}{16}$″	$\frac{9}{16}$″	24,750
500	910	320	15′ 8$\frac{3}{4}$″	65$\frac{1}{4}$′	123$\frac{1}{4}$	8$\frac{1}{2}$″	67$\frac{1}{4}$″	54″	119$\frac{1}{8}$′	61″	123$\frac{1}{2}$	61″	118$\frac{3}{4}$	14′ 11$\frac{3}{4}$″	60″	64″	42″	2$\frac{1}{8}$″	$\frac{5}{8}$″	46,000

tate ventilation, and repair to either coil. The upper half of the field frame can be lifted and removed to give access to the armature.

Fig. 55, shows the Card Electric Company's Belt-Driven 100 K. W. generator. This is a compound-wound quadripolar machine, with carbon brushes. It has two base ratchet levers for belt tightening, and one ratchet lever below the pedestal for moving the field-frame. By the use of this ratchet-

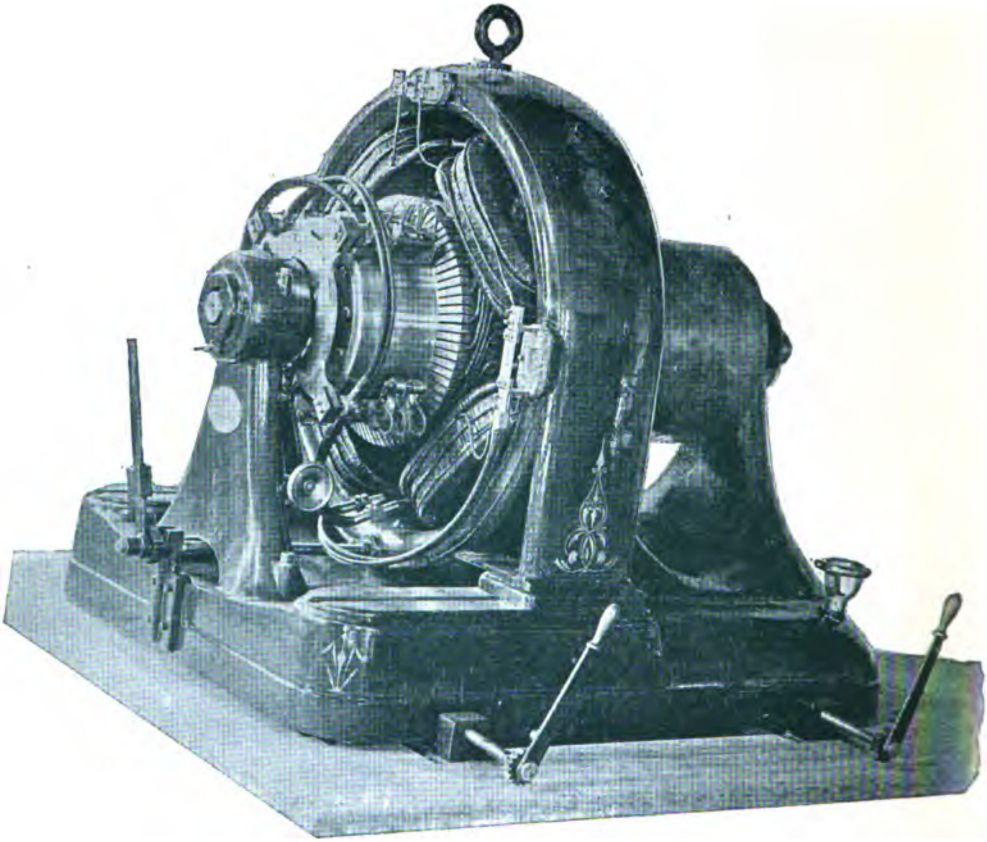


Fig. 55—"Card" 100 K. W. Belt-Driven Generator.

lever the field-frame, which is cast in one piece, can be moved along the base, and by removing the front pedestal can be moved entirely clear of the armature.

Fig. 56, shows a "C & C" Electric Company's belt-driven generator. It is sextipolar and compound-wound.

Fig. 57, shows an Excelsior Electric Company's multipolar belt-driven generator, compound-wound, and with carbon brushes. The dimensions of these machines of the slow-speed type are given in the accompanying table:

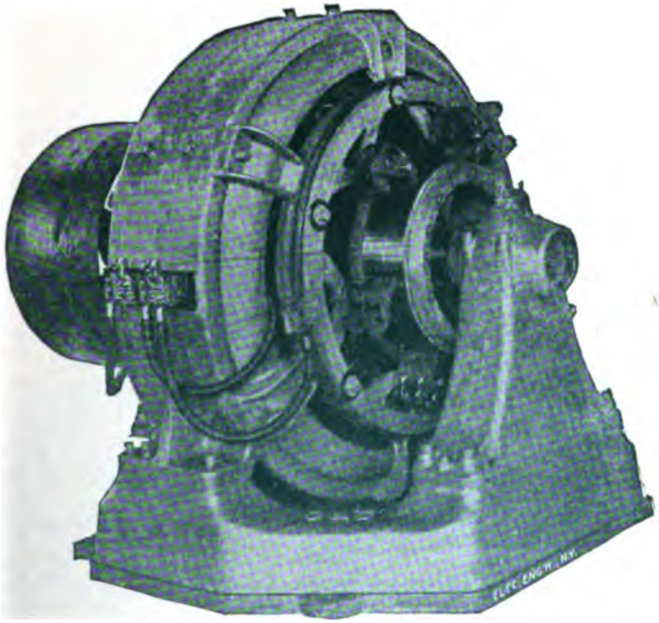


Fig. 56—C. & C. 6-Pole Generator.

Fig. 58, shows a 100 K. W. generator of the Triumph Electric Company. These machines are quadripolar, in sizes from ¾ to 45 K. W. inclusive, and sextipolar in sizes of 60, 80, and 100 K. W. They are constructed in two classes; i. e., for slow speeds and for moderate speeds, the moderate-speed

TABLE OF DIMENSIONS OF SLOW SPEED BELT-DRIVEN GENERATORS OF THE EXCELSIOR ELECTRIC COMPANY.

CLASSIFICATION.				VOLTS.	Amperes Full Load.	Weight Pounds	DIMENSIONS.		
							Pulleys.		Floor Space.
No.	H. P.	K.-W.	Speed.				Diam.	Face	
3	3.	2.2	700	125,250,500	17.5 8.75 4.37	337	6	8	$18\frac{3}{4}$ x 30
4	5.	3.75	700	125,250,500	30. 15. 7.5	511	7	4	$23\frac{3}{4}$ x 30
5	7.5	5.62	700	125,250,500	45. 22.5 11.25	704	8	5	29 x 33
6	10.	7.5	700	125,250,500	60. 30. 15.	979	9	5	$30\frac{3}{8}$ x 33
7	15.	11.25	700	125,250,500	90. 45. 22.5	1115	10	6	$34\frac{1}{4}$ x 41
8	20.	15.	700	125,250,500	120. 60. 30.	1374	12	8	$44\frac{1}{16}$ x 48
9	30.	22.5	700	125,250,500	180. 90. 45.	1851	15	10	$48\frac{3}{4}$ x 48
10	45.	33.75	660	125,250,500	270. 135. 67.5	3471	20	12	$62\frac{1}{4}$ x 54
11	60.	45.	660	125,250,500	360. 180. 90.	3866	26	12	$64\frac{1}{4}$ x 54
12	85.	65.	600	125,250,500	520. 260. 130.	5400	26	14	$67\frac{1}{8}$ x 54

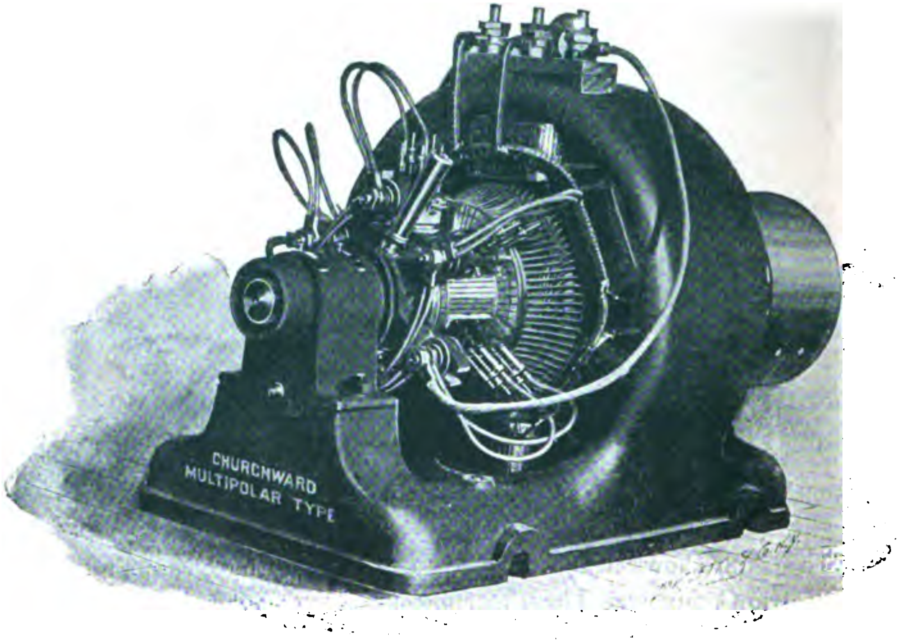


Fig. 57—Excelsior 6-Pole Belt-Driven Generator.

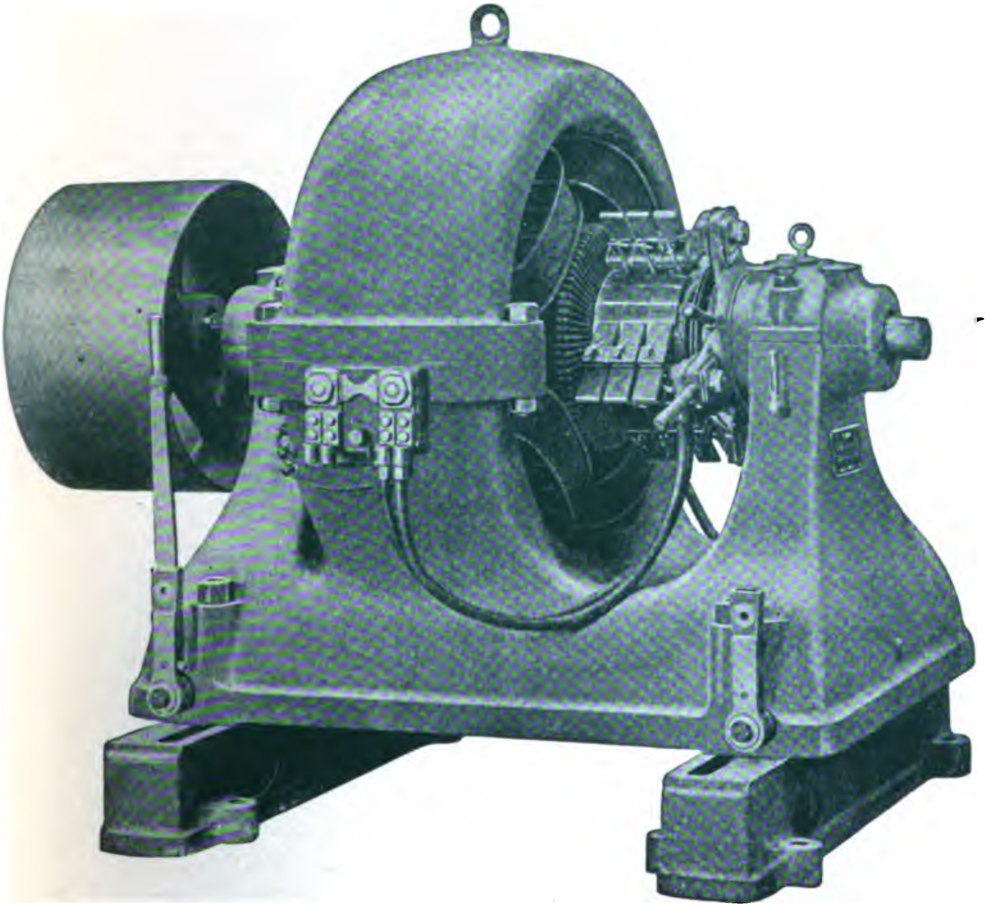


Fig. 59—" Short " Belted Type of Lighting and Power Generator of the Walker Company.

machines having roughly about 50% higher speed than the slow-speed machines of the same capacity.

Fig. 59, shows a Walker Company's quadripolar belt-driven type of generator, with four sets of brushes, ratchet belt-tighteners, and iron-clad armatures. Fig. 60, shows with the accompanying table the dimensions of these machines and their foundations.

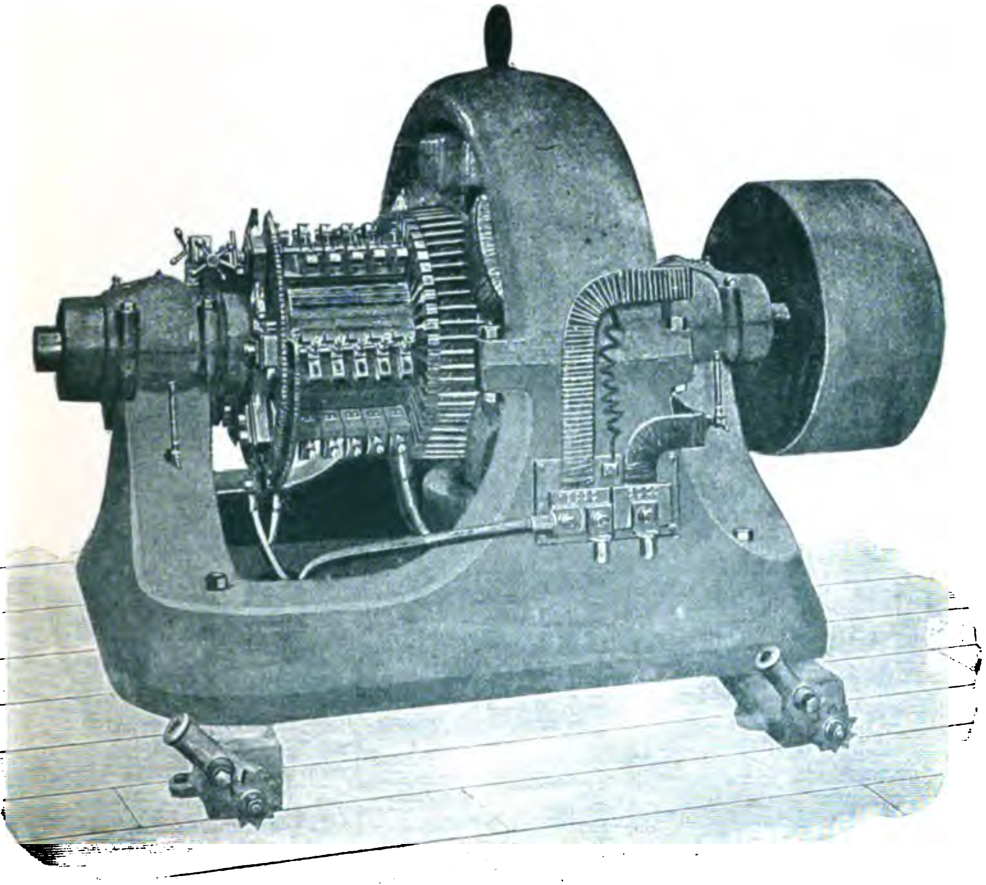


Fig. 58—Triumph Electric Company's 100 K. W. Generator.

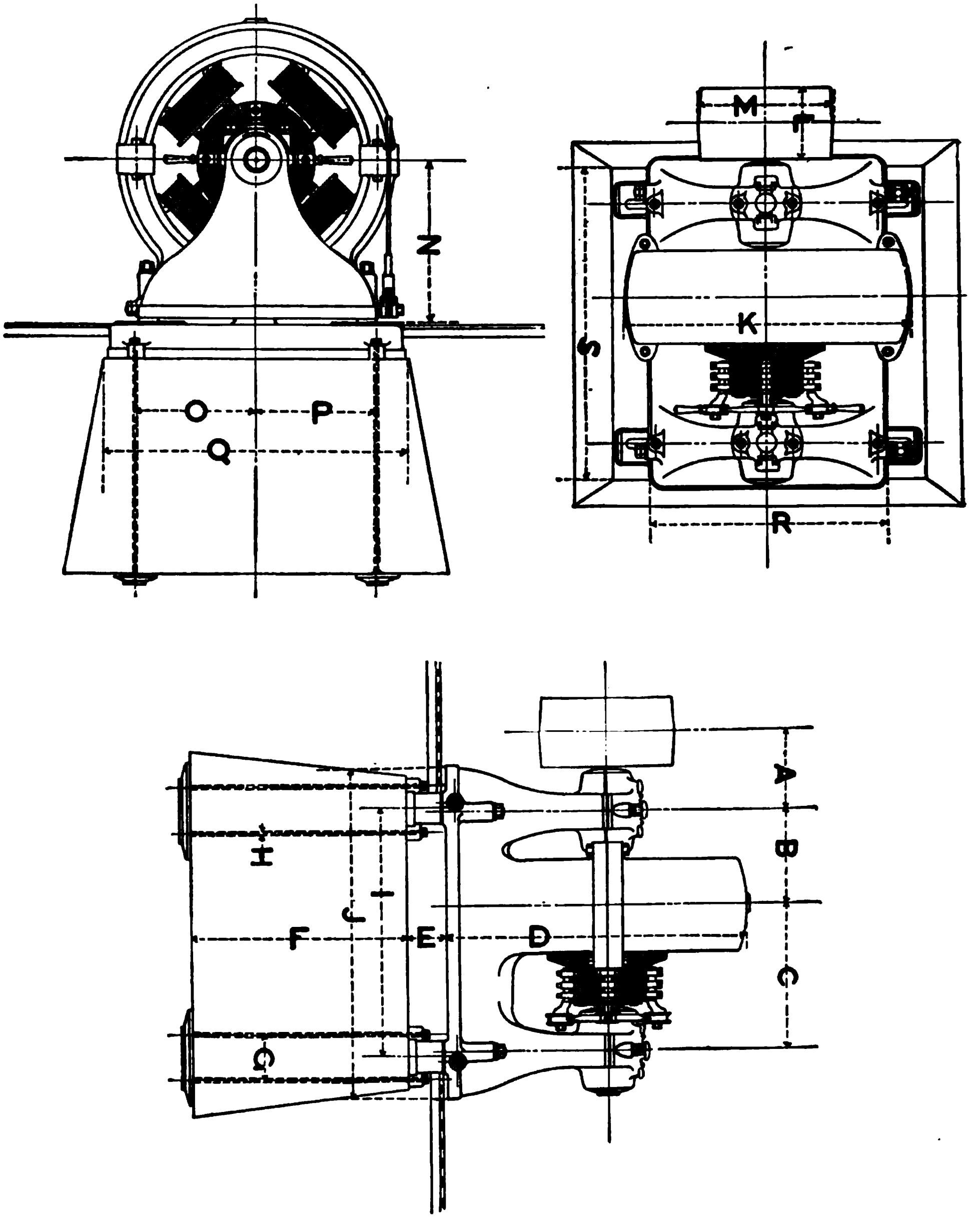


Fig. 60—Dimensions of "Short" Quadripolar Belt-Driven Generators.

TABLE OF DIMENSIONS FOR "SHORT" QUADRIPOLAR BELT-DRIVEN GENERATORS.

K. W.	50	75	100	150
HP	67	100	135	200
SPEED	900	800	750	600
WEIGHT	8300	11000	13650	18300
A	13½	14	16	18
B	17¼	18	19½	21¼
C	25¾	28	30	32¾
D	50¼	54½	61	67¼
E	8¾	8¾	8¼	8¼
F (Min.)	60	60	72	72
G	10½	10½	10½	10½
H	1¼	1¼	1¼	1¼
I	45¼	48¼	51¾	56¼
J	59	62½	68½	75
K	44½	49⅞	56	62⅝
L	12	12	14	16
M	22	22	27½	30
N	28¼	30¼	33¼	36¼
O	20	20	24	27
P	20	20	24	27
Q	56	56	62	70
R	40	42	47	53
S	60	64	68	75

Fig. 61, shows a Western Electric Company's belt-driven quadripolar generator, wound for 120 volts, 240 volts, and for 550 volts, with iron-clad drum-armatures. They have four sets of carbon brushes, and are compound-wound. The accompanying table gives the principal data concerning them.

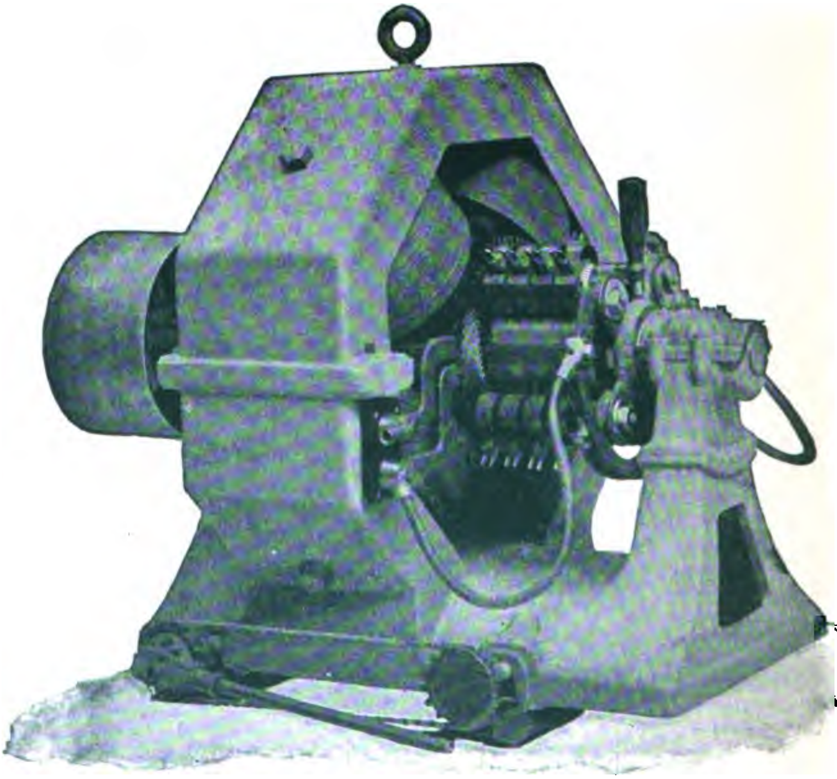


Fig. 61—"Western Electric" Belt-Driven Multipolar Dynamo.

For small bipolar motors and generators the Western Electric Company use the type of machine shown in Fig. 62. This cut shows a standard motor driving a generator wound for very low voltages to be used as a "booster," or for charging storage batteries.

TABLE OF WESTERN ELECTRIC COMPANY'S SLOW SPEED BELT-DRIVEN MULTIPOLAR DYNAMOS.

KILOWATTS.	POLES.	SPEED.	VOLTS.	AMPERES.	SHIPPING WEIGHT.	FLOOR SPACE PERPENDICULAR TO SHAFT.	FLOOR SPACE PARALLEL TO SHAFT.	HEIGHT FROM FLOOR TO CENTER OF SHAFT.	TOTAL HEIGHT.	PULLEY—DIAMETER.	PULLEY—FACE.
						INCHES.	INCHES.	INCHES.	INCHES.	INCHES.	INCHES.
½	4	1900	120	4.2	220	15	18	8⅝	17	4	2½
	“	2000	240	2.	“	“	“	“	“	“	“
	“	2200	550	1.	“	“	“	“	“	“	“
3	4	1100	120	25	670	23⅜	27½	13¼	24⅝	5¾	3½
	“	“	240	12	“	“	“	“	“	“	“
	“	1200	550	5.5	“	“	“	“	“	“	“
5	4	1100	120	40	1000	25¾	33	15¼	28	8	4
	“	“	240	20	“	“	“	“	“	“	“
	“	1150	550	9	“	“	“	“	“	“	“
9	4	975	120	75	1660	29¾	41⅞	17¾	34⅝	9	6½
	“	“	240	37	“	“	“	“	“	“	“
	“	1050	550	16	“	“	“	“	“	“	“
12	4	775	120	100	2700	41	50	20¼	40½	12	7½
	“	“	240	50	“	“	“	“	“	“	“
	“	875	550	21	“	“	“	“	“	“	“
17	4	650	120	140	3075	53	52	19¼	39¼	15	9
	“	“	240	70	“	“	“	“	“	“	“
	“	725	550	30	“	“	“	“	“	“	“
20	4	650	120	165	3800	41	53¼	22½	45	16	9½
	“	“	240	85	“	“	“	“	“	“	“
	“	725	550	38	“	“	“	“	“	“	“
30	4	540	120	250	6000	50	61½	26	52½	20	12½
	“	“	240	125	“	“	“	“	“	“	“
	“	600	550	55	“	“	“	“	“	“	“
40	4	475	120	330	6650	50	63¼	26	52½	23	15
	“	“	240	170	“	“	“	“	“	“	“
	“	525	550	70	“	“	“	“	“	“	“
50	4	450	120	420	10300	50	74	29½	61	24	16
	“	“	240	210	“	“	“	“	“	“	“
	“	500	550	90	“	“	“	“	“	“	“
60	6	460	120	500	8700	76	68⅝	31¾	60¼	32	16
	“	“	240	250	“	“	“	“	“	“	“
	4	650	240	250	7500	50	73¾	27¾	55¾	20	18½
	“	“	550	110	“	“	“	“	“	“	“
75	6	565	120	625	7800	76	71	31¾	60¼	32	16
	“	“	240	310	“	“	“	“	“	“	“
	4	400	240	310	13900	60⅝	87⅝	34½	69⅜	30	19
	“	“	550	135	“	“	“	“	“	“	“
100	6	450	120	830	13200	87	83½	33 13/16	63 13/16	38	20
	“	“	240	420	“	“	“	“	“	“	“
	4	650	240	420	13900	60⅝	87⅝	34½	69⅜	25	19
	“	“	550	180	“	“	“	“	“	“	“
250	8	400	240	1040	29000	104	126	43½	83½	46	32
	“	425	550	455	“	“	“	“	“	“	“

Fig. 63, represents the Keystone Electric Company's belt-driven type of generators and motors. This machine has four poles and four sets of carbon brushes. The iron-clad armature of this machine is shown in Fig. 64.

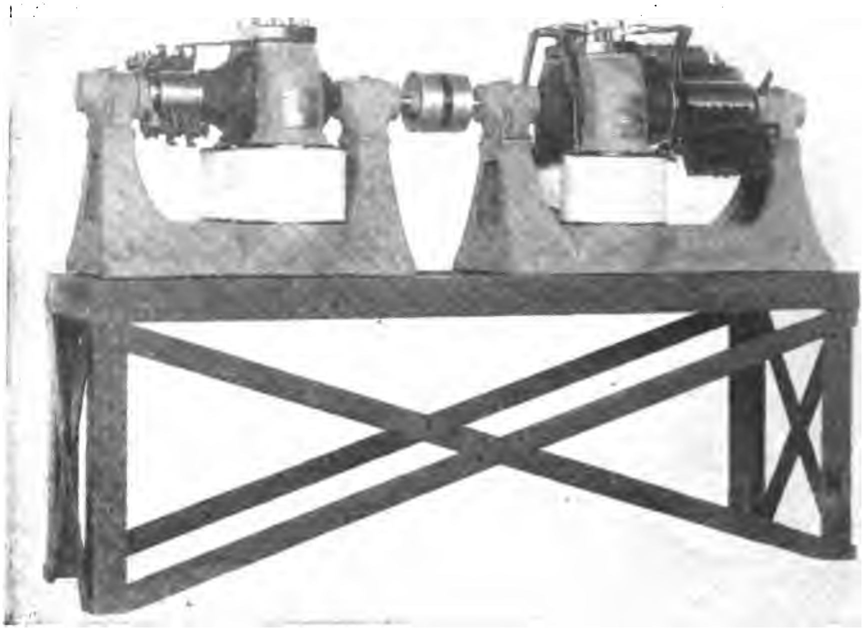


Fig. 62—"Western Electric" Bipolar Dynamo.

The Siemens and Halske Electric Company's multipolar belted type of generator is represented in Fig. 65. This machine has its field magnets of the square iron-clad type, and employs one pair of carbon brushes. A bipolar generator of the Siemens and Halske Electric Company, is represented in Fig. 66. Here, the field magnets are of the upright type, and are so shaped that there is a greater magnetic attraction on the armature in the upward, than in the downward direction, so as to reduce the weight of the armature in its bearings, and thus lessen the friction of rotation.

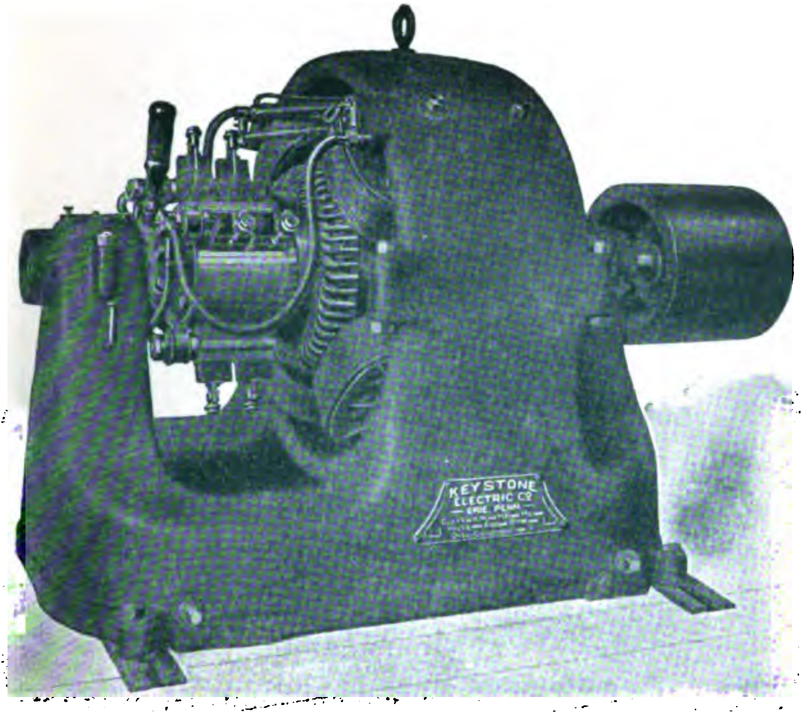


Fig. 63—Keystone Electric Company's Belt-Driven Type of Generator.

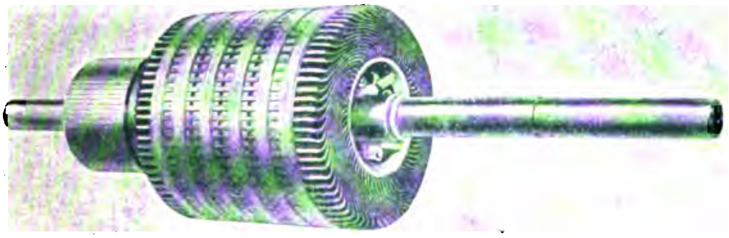


Fig. 64—Armature for "Keystone" Belt-Driven Type of Generator.

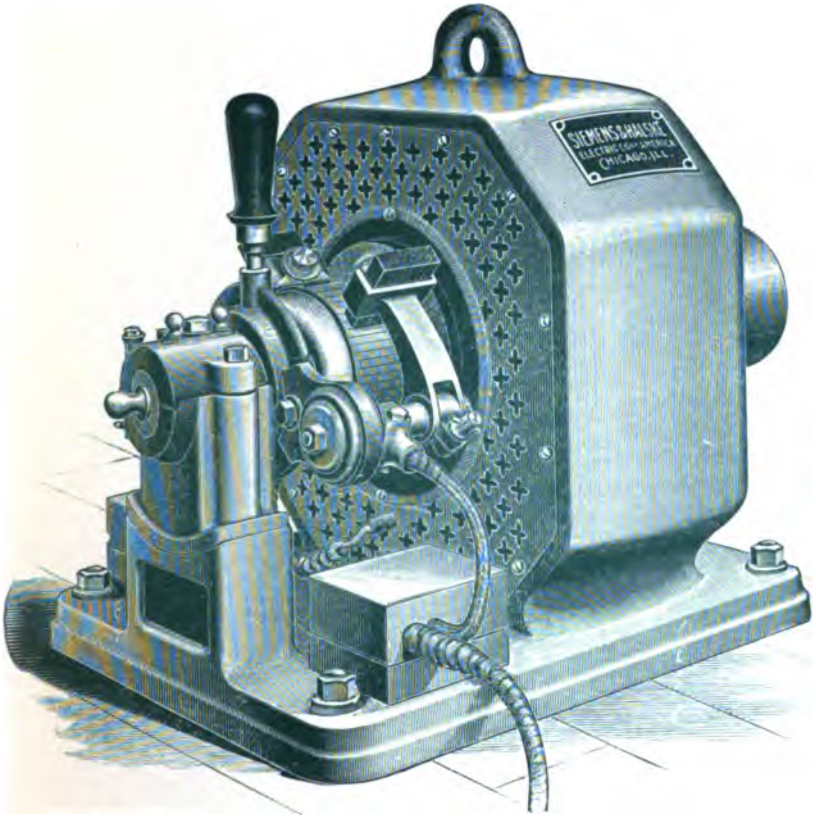


Fig. 65—Siemens & Halske Belt-Driven Multipolar Generator.

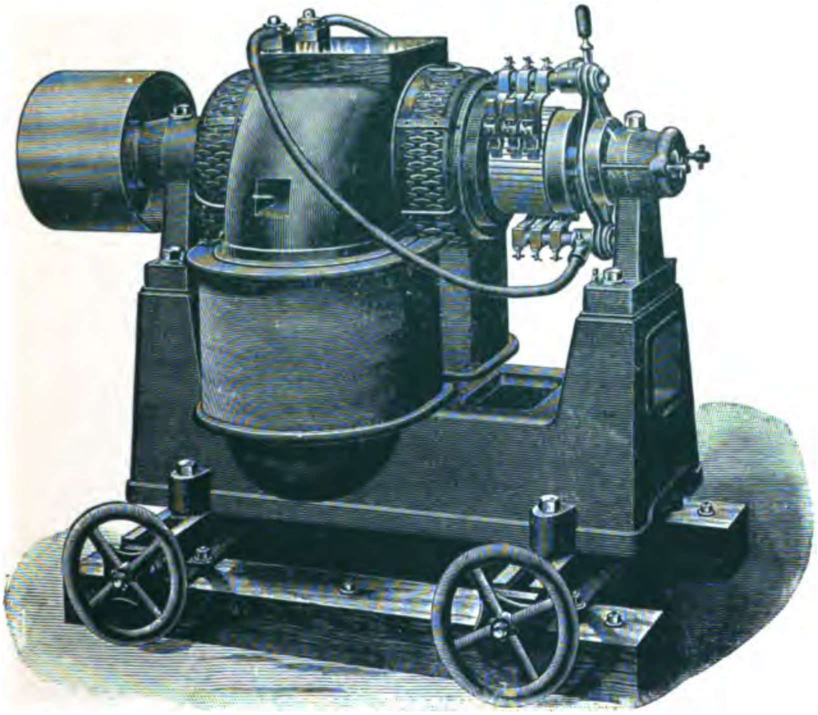


Fig. 66—Siemens & Halske Belt-Driven Bipolar Generator.

Fig. 67, shows a vertical bipolar dynamo of the Commercial Electric Company. These machines are wound for 110 volts and 500 volts. Their armatures are of the Gramme-ring type and are surface-wound. That is to say, the wire lies on the surface of the armature instead of being buried in slots in the surface of an iron-clad armature. One of these armatures is shown in Fig. 68. The armature wires are firmly bound upon the surface of the armature by soldered bands of wire laid over mica strips. Fig. 69, shows a Commercial Electric Company's quadripolar dynamo, compound-wound. In small sizes this can be erected on the wall, ceiling, or floor.

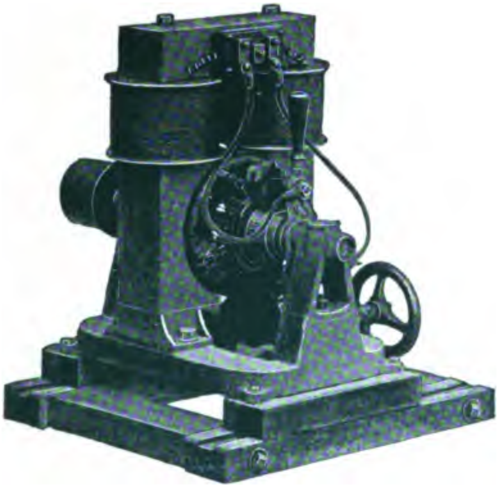


Fig. 67—"Commercial Electric" Bipolar Dynamo.

Fig. 70, shows a Crocker-Wheeler Electric Company's, size 225, quadripolar belt-driven machine. As a generator it has a capacity of 200 K. W. at 450 revolutions per minute. The machine has three bearings, and the pedestals, base and lower half of the field frame form a single iron casting. The poles are of cast steel, cast into the iron field-frame. The armature is wound with cable conductors fastened to the commutator by locking double screws without solder. The machine, when used as a continuous-current motor has a capacity of 225 H. P. at 450 revolutions per minute. It is wound for 115, 230, or 500 volts. Its shipping weight is 16 tons.

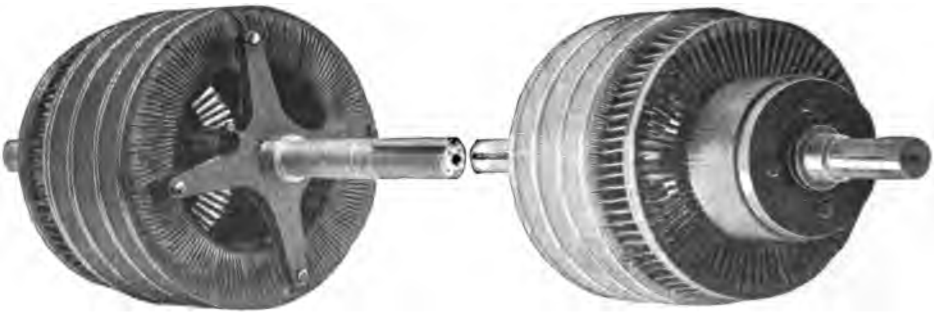


Fig. 68—"Commercial" Gramme Ring Armature.

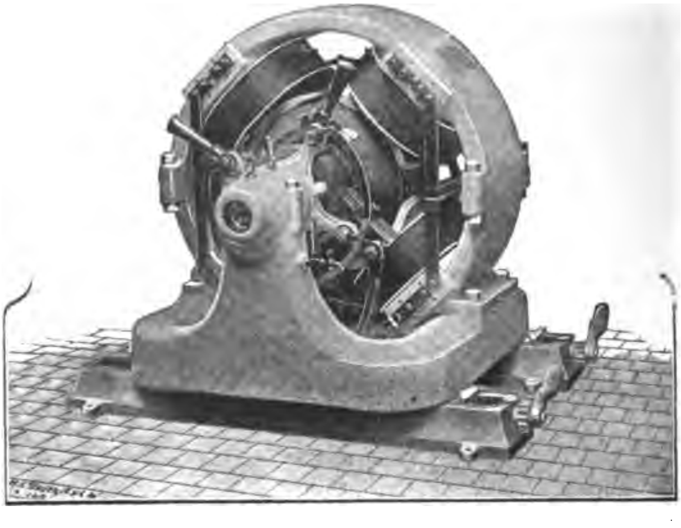


Fig. 69—"Commercial" Multipolar Dynamo.

Fig. 71, shows a Westinghouse Electric and Manufacturing Company's "Type 5" switchboard for two 62.5 K.W. continuous-current 125-volt generators in an isolated plant. It is a marble switchboard with five panels, A, B, C, D, E. A and B, are generator panels, one for each of the two generators. C, is a voltmeter panel. D and E, are feeder panels.

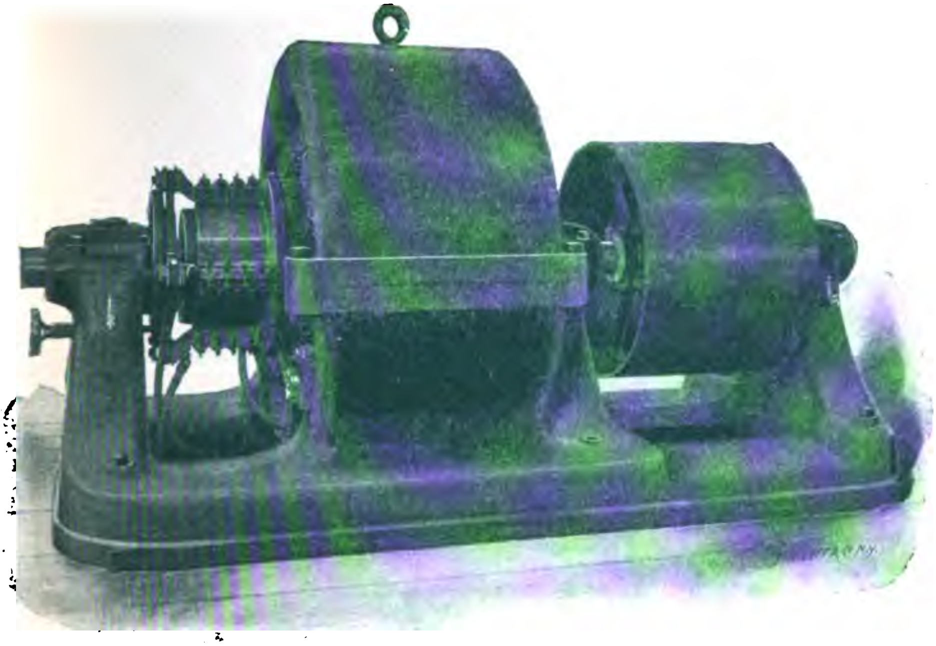


Fig. 70—Crocker-Wheeler Quadripolar Belt-Driven Dynamo.

Panels A and B, carry the main generator switches S, S′, circuit breakers, or automatic overload switches O, O′, field rheostats F, F′, and generator-circuit ammeters M, M′. Panel C, carries two voltmeters V, V′, one for indicating the pressure at the bus-bars, and the other for indicating the pressure of either generator. Panels D and E, each carry six double-pole switches for the control of as many separate circuits from the bus-bars.

A switch-board of this type is frequently employed in a large building, such as a hotel, where the night load may call for two generators, while the day load only demands one. Each floor, or group of rooms, may be controlled by a separate

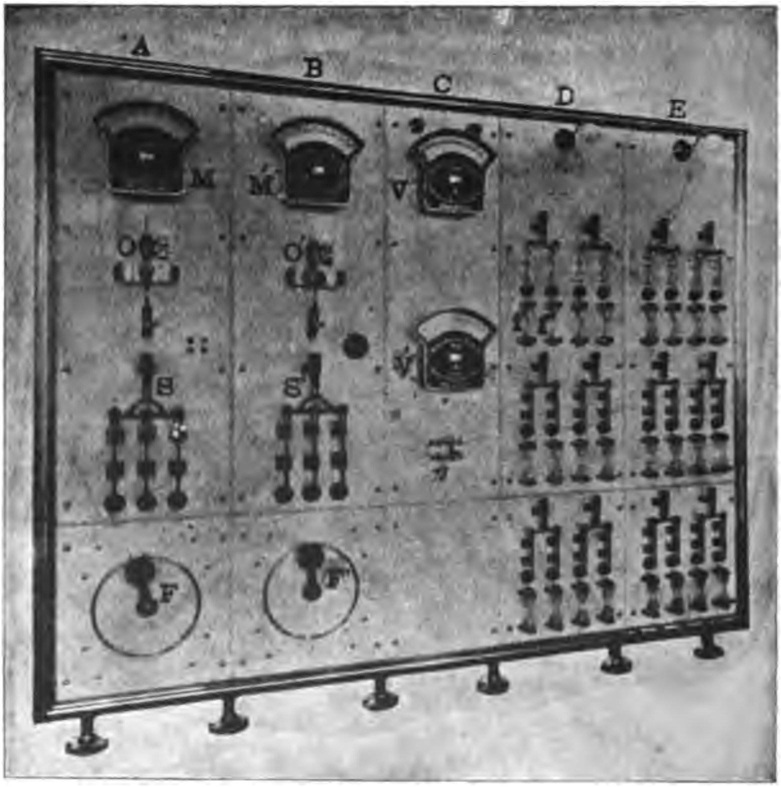


Fig. 71—"Westinghouse" Type 5 Switchboard.

feeder switch on the panels D and E, through fuses f, f, a pair of such fuses being connected with each switch.

Fig. 72, shows the back of this switchboard. Three main conductors come from the compound-wound generators to each of the generator panels A and B. The negative terminal brushes are connected to P, P'; the positive terminals, including the series-field coils to N, N′, and the positive brushes, or junction between series-field and armature, to n, n′, respectively. When the main switches are closed, P and P′, are connected to the upper bus-bar U, through connections between p and p″, also p′ and p‴ not shown, containing strip resistances, the drop of pressure in which serves to operate the ammeters M, M′. Connection is maintained between p″ and u, also between p‴ and u′, through auto-

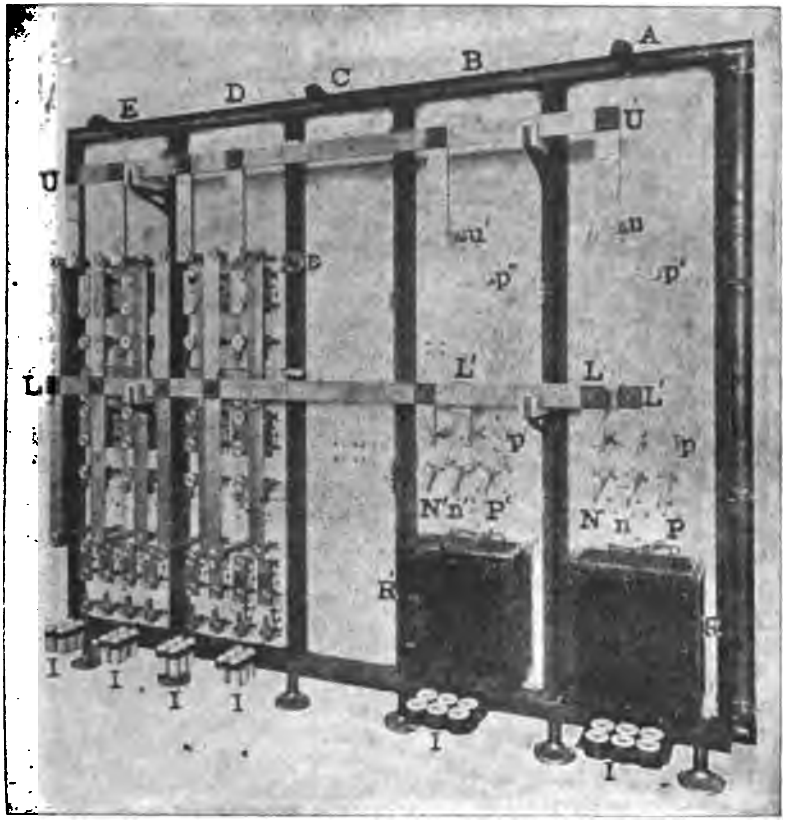


Fig. 72—Rear View of Switchboard in Fig. 71.

matic circuit breakers, O, O′, which interrupt these circuits should the currents passing through them become excessive.

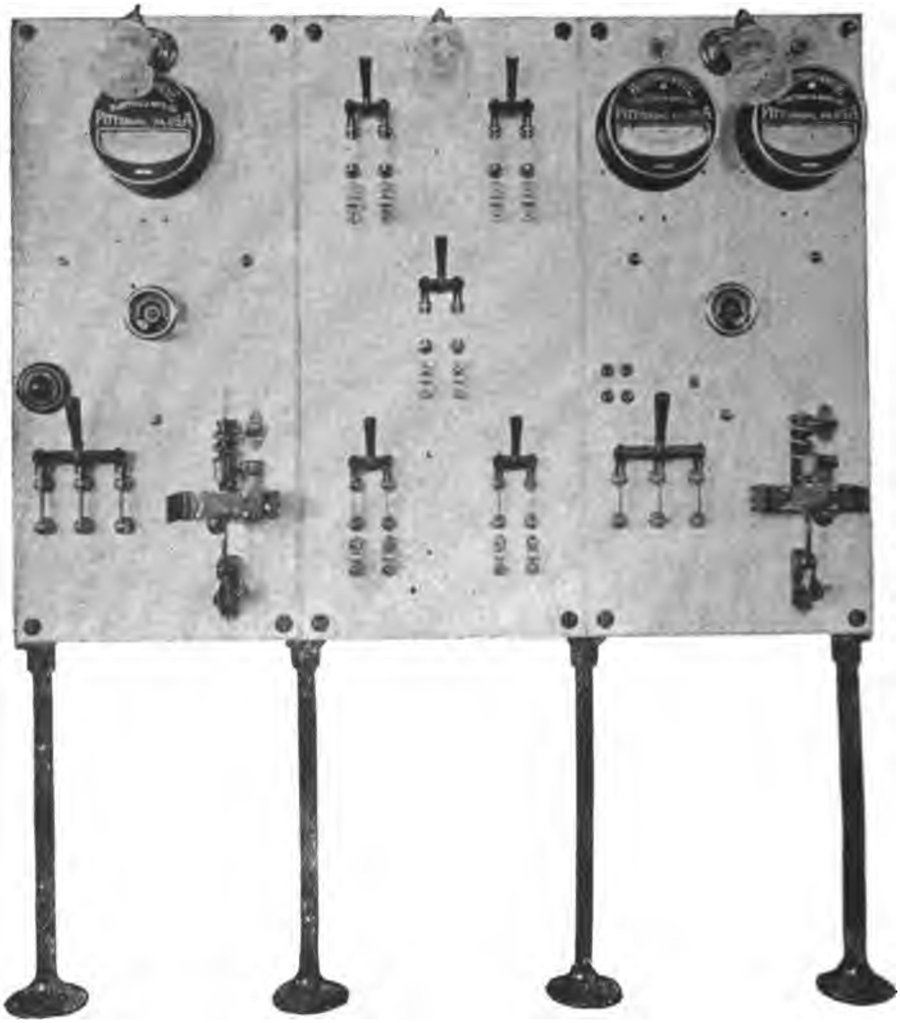


Fig. 73—A Westinghouse Isolated Plant Switchboard.

The closure of the main switches also puts the terminals N and N′, in connection with the lower bus-bar L, L. L′, L′, is a separate short bus-bar, called the equalizing bar, connecting n and n′, through the middle blades of the main switches.

All the feeder switches on panels D and E, are supplied from the upper and lower bus-bars at their upper jaws, while the circuit wires are connected to terminals t, t′, taken from beneath the fuses. I, I, I, are groups of insulators through which the various conductors are led. R, R′, are the field-rheostat boxes. *S*, is a small switch for lighting up the pilot lamps.

A Westinghouse Electric and Manufacturing Company's isolated plant switch-board for two 37.5 K.W. 125-volt generators, and five 200-ampere feeders is shown in Fig. 73. Here the outside panels are devoted to the generators and the middle panel to the feeders.

In setting up a belt-driven generator, the same degree of care is not required with the foundation as with a direct-coupled generator, since the engine foundation is independent of the dynamo foundation. The dynamo foundation may, therefore, be laid at any time subsequent to the laying of the engine without any difficulty. Small belt-driven machines run upon steel ways, which in their turn rest on wooden base frames bolted to the floor. Larger machines are supported on brick foundations of the type shown in Fig. 60.

In any engine room employing horizontal belts, it is always good practice to place by the side of the belt, a hand-rail of wood or iron in such a position as to prevent persons from approaching the moving belt too closely.

In removing a generator, either of the direct-driven or belt-driven type, from its circuit, the main switch is first opened, thereby breaking the external circuit. The field switch may then be opened, thereby breaking the field circuit; or, the field switch may be left closed until the machine has come to rest. But the brushes should in no case be lifted until the armature has come to rest; or, at least until after the field circuit has been broken.

CHAPTER IV.

CONTINUOUS-CURRENT CENTRAL-STATION GENERATORS.

CENTRAL-STATION continuous-current generators are nearly always installed either for 500-volt electric railroad supply, or for 140-volt incandescent lighting and motor supply. Both of these classes of generators, in modern types, are almost always direct-connected, for the reason that they have to be arranged for economy of space and operation in comparatively large units, and these large units are most conveniently driven by direct coupling to the engine shafts. The typical modern central-station generator is directly driven by a large compound engine, although a turbine is often employed where water-power is commercially available. At full load the efficiency of large generator units in which all frictions are reduced to a minimum by the use of the minimum number of bearings, is quite high, approximating 90 per cent. That is to say, the *electric horse-power* delivered by the dynamo at its terminals, as reckoned from the volts multiplied by the amperes and divided by 746, differs by about ten per cent from the indicated horse-power of the steam engine directly coupled to the same. Thus, a 550 K. W. 500-volt generator, will deliver 1,000 amperes at a pressure of 550 volts. This represents $\frac{550,000}{746} = 737.3$ E. H. P. If the indicated horse-power at the engine is 838, the efficiency of the generating unit is $\frac{737.3}{838} = 0.88$, or 88%; representing a total loss of about 101 horse-power, or 12%, in mechanical and electrical frictions through the engine and generator. But at no load, the frictions would not, probably, fall below 65 H. P. Consequently, at a very small output, the relative loss in friction would be high, corresponding to a low efficiency.

A direct-connected dynamo of the Westinghouse Electric and Manufacturing Company is shown in Fig. 74. This dynamo is intended to supply current at 550 volts pressure, so as to maintain a pressure of, approximately, 500 volts at the trolley wires, as is required in railway work, and is, therefore, called a railway generator. The machine has 10 poles and 10 sets of carbon brushes. It is mounted on the engine shaft close to the large fly-wheel FF, the spokes of which are not visible, since the photograph was taken with the machine in motion. The brush-holder circle is set and adjusted by the wheel W, supported from the field frame MM.

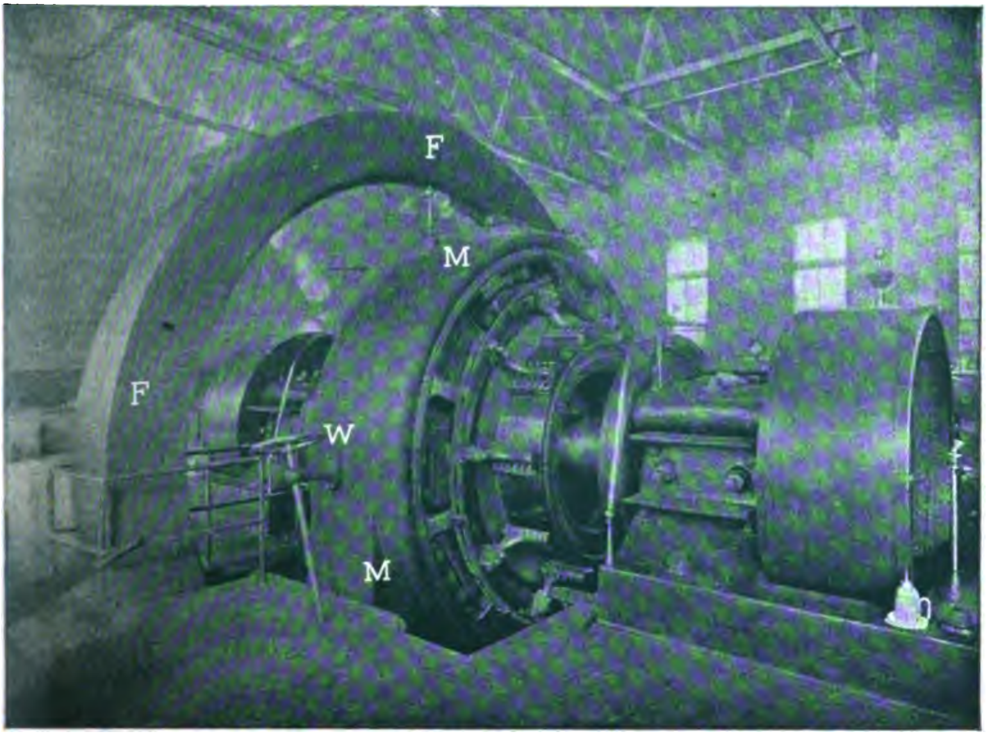


Fig. 74—"Westinghouse" Direct-Connected Railway Generator.

APPROXIMATE DIMENSIONS OF SLOW-SPEED WESTINGHOUSE ELECTRIC COMPANY'S ENGINE-TYPE RAILWAY GENERATORS.

KW.	Amperes at 550 Volts.	Poles.	R. P. M.	Approx. Net Weight.	A	B	C	D	E	F	G	H
250	455	10	90	50,000	18″	32″	67¼″	124¼″	144″	39″	57″	114″
250	455	10	100	50,000	18″	32″	67¼″	124¼″	144″	39″	57″	114″
400	725	10	90	70,000	22″	39″	73¾″	138¾″	176″	47½″	63½″	126″
400	725	10	100	70,000	22″	39″	73¾″	138¾″	176″	47½″	63½″	126″
500	910	10	80	100,000	21″	39″	80¼″	152¾″	171″	42″	70″	144″
500	910	10	90	100,000	21″	39″	80¼″	152¾″	171″	42″	70″	144″
500	910	10	100	100,000	21″	39″	80¼″	152¾″	171″	42″	70″	144″
800	1455	10	80	135,000	24″	48″	88¼″	166¾″	204″	52½″	76″	
800	1455	10	90	135,000	24″	48″	88¼″	166¾″	204″	52½″	76″	
1200	2180	12	75	185,000	22″	52″	100¾″	191⅝″	252″	53½″	88½″	192″
1200	2180	12	80	185,000	22″	52″	100¾″	191⅝″	252″	53½″	88½″	192″
1500	2730	14	75	200,000	23″	56″	109¾″	210″	276″	55″	97½″	204″
1500	2730	14	80	200,000	23″	56″	109¾″	210″	276″	55″	97½″	204″

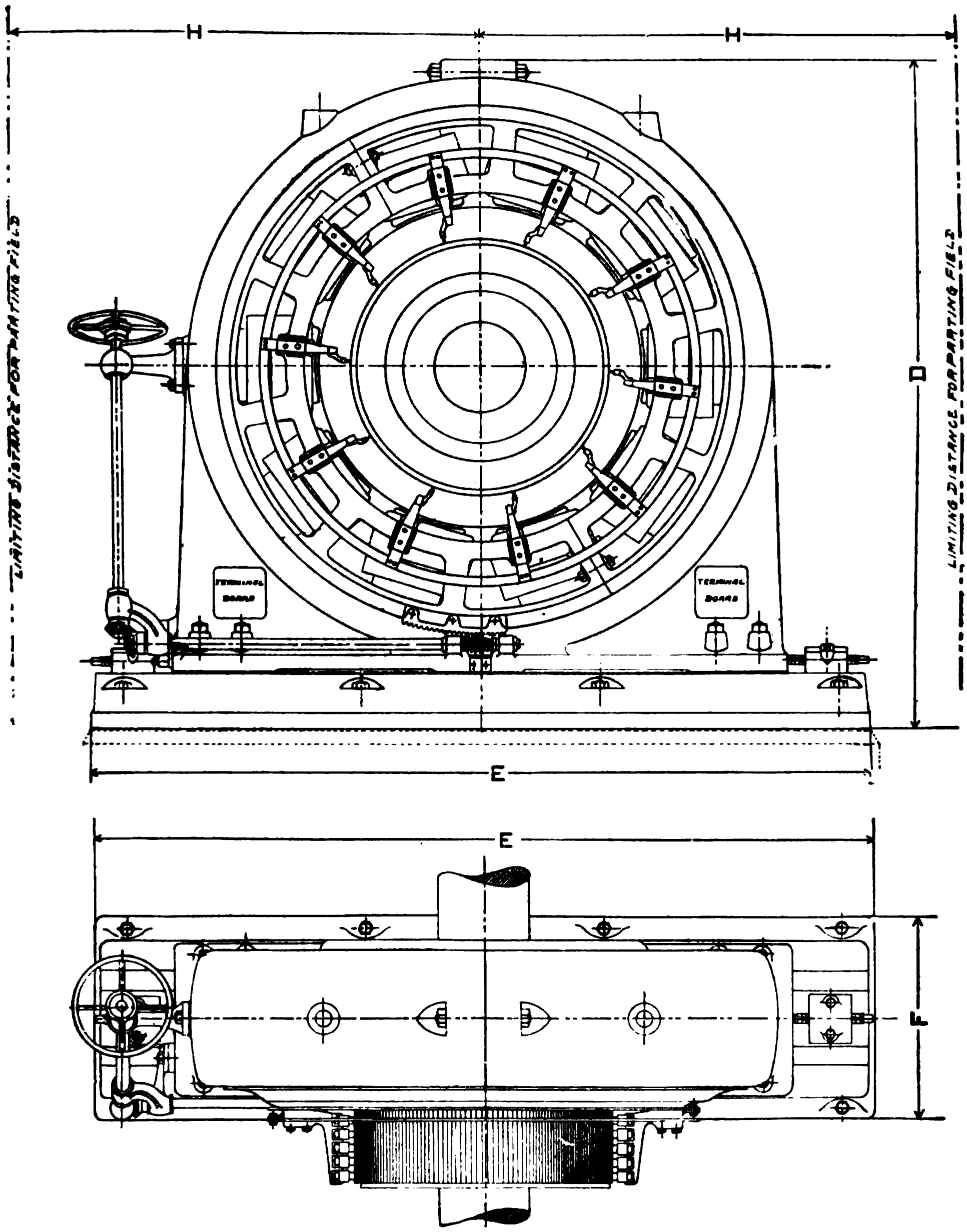

H
H
LIMITING DISTANCE FOR PARTING FIELD
LIMITING DISTANCE FOR PARTING FIELD
D
TERMINAL BOARD
TERMINAL BOARD
E
E
F

Fig. 75—Dimensions of "Westinghouse" Direct-Connected Railway Generator.

The dimensions of these machines in standard sizes is shown in Fig. 75 and 76, in connection with the accompanying table.

It will be seen that the speed of rotation varies from 100 to 75 revolutions per minute, and the output from 5 to 7.5 watts per pound of weight. The field frames are divided into two vertical halves, for convenience of access to the armature, the halves being capable of separation by keys and ways, as already explained in connection with direct-driven 250-volt generators. The field magnets are compound-wound, and the machines are over-compounded 10%, from no load to full load, so that the pressure tends to increase instead of decrease with increase of load. That is to say, the series-wound coils have a preponderating influence upon the pressure generated by the machines.

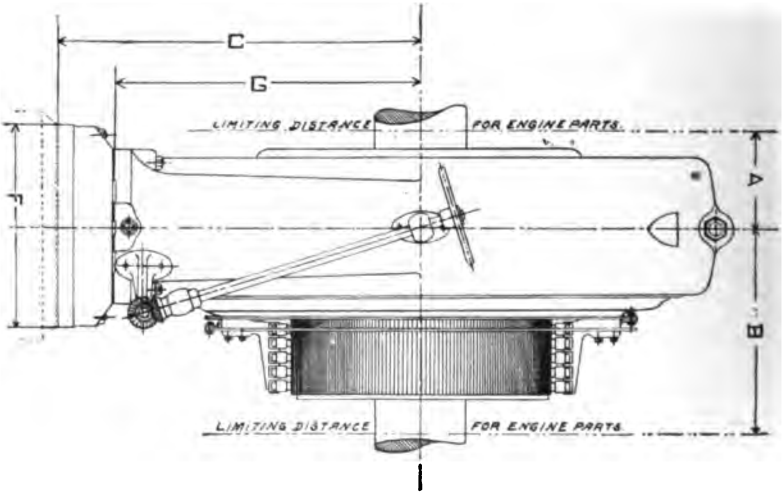


Fig. 76—Dimensions of "Westinghouse" Direct-Connected Railway Generator.

Fig. 77, shows a Westinghouse Electric Company's 500-K.W. continuous-current belt-driven Railway generator, compound-wound for 550 volts.

Fig. 78, represents a Siemens and Halske 500 K.W. direct-connected railway generator, having six poles and six sets of brushes. Here, as in the form already illustrated in Figs. 6 and 7, the armature revolves outside the fixed field frame, and the armature conductors form, on the outside of the armature, the commutator upon which the brushes rest. a and b, are the main conductors passing through insulators through the floor to the switch-board.

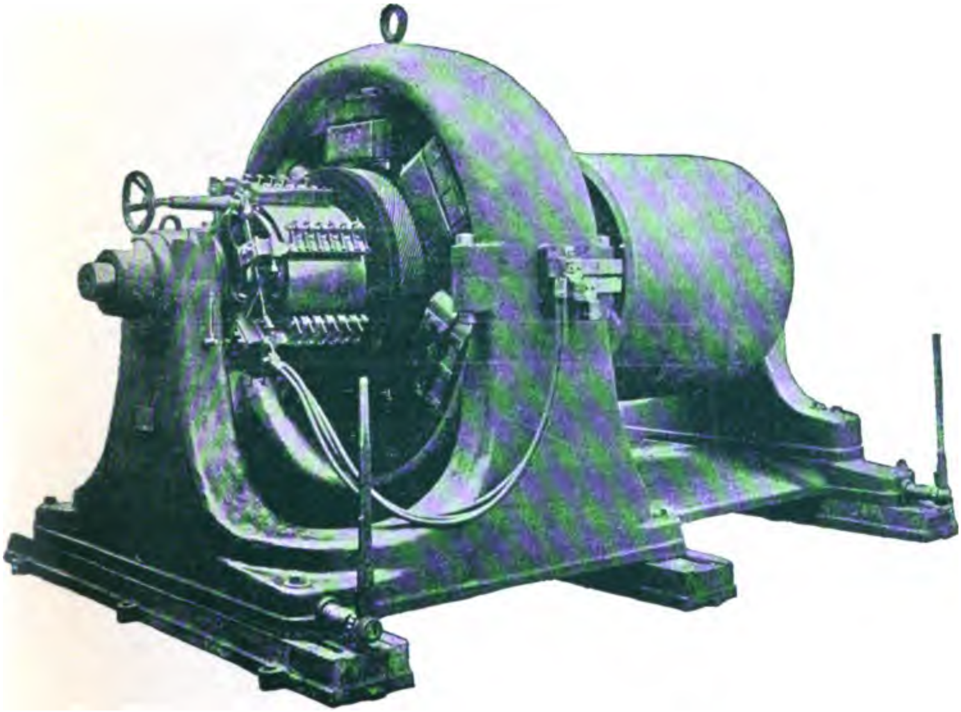


Fig. 77—A "Westinghouse" 500 K.W. Direct-Current Belt-Driven Railway Generator.

Fig. 79, shows a Walker Company's direct-connected 800 K. W. railway generator, having 12 poles. At 550 volts the full load of this machine will be 1,455 amperes. The details

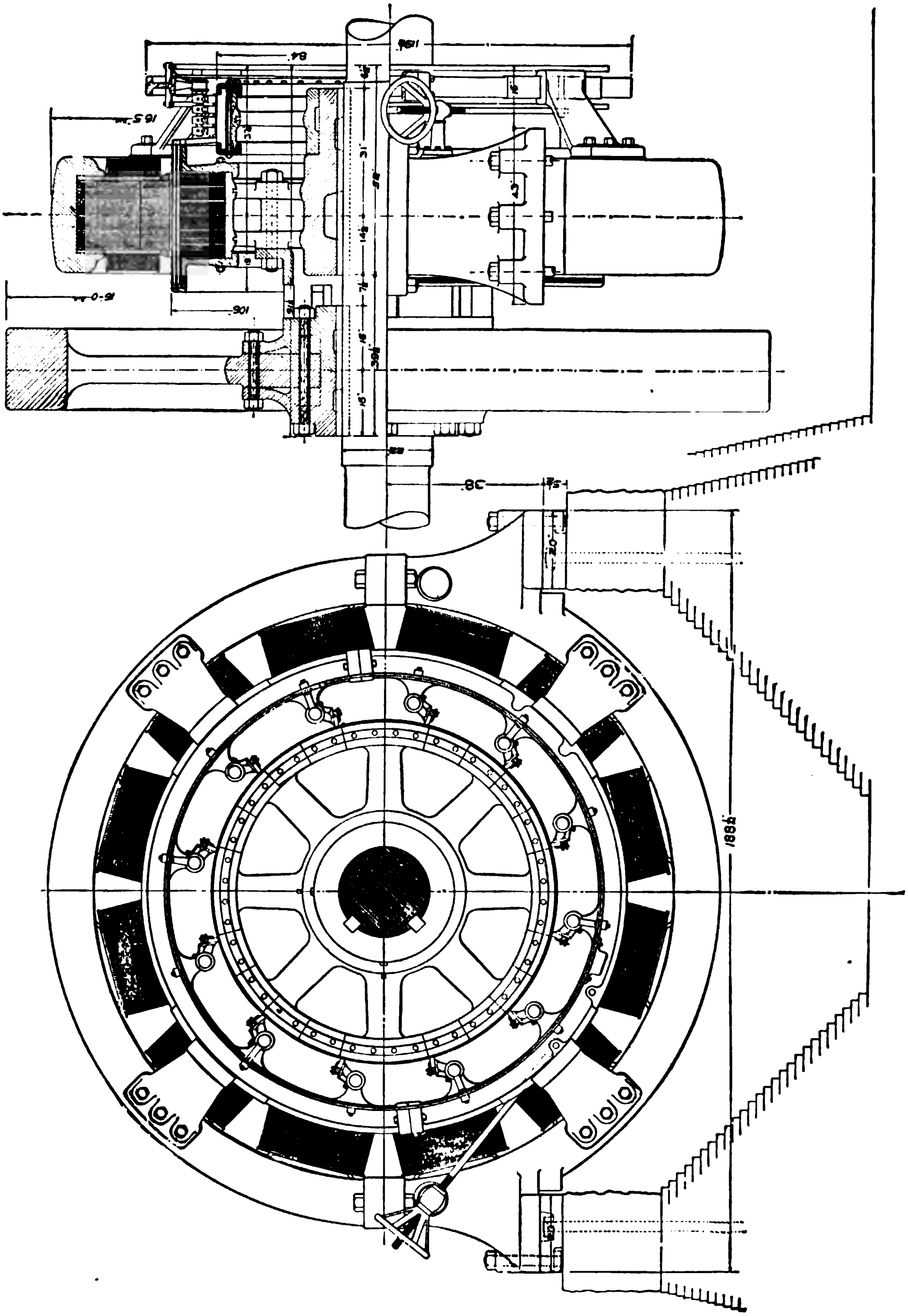


Fig. 80—Side Elevation, Half Section and End Elevation of the Walker Company "Short" 800 K. W. Railway Generator.

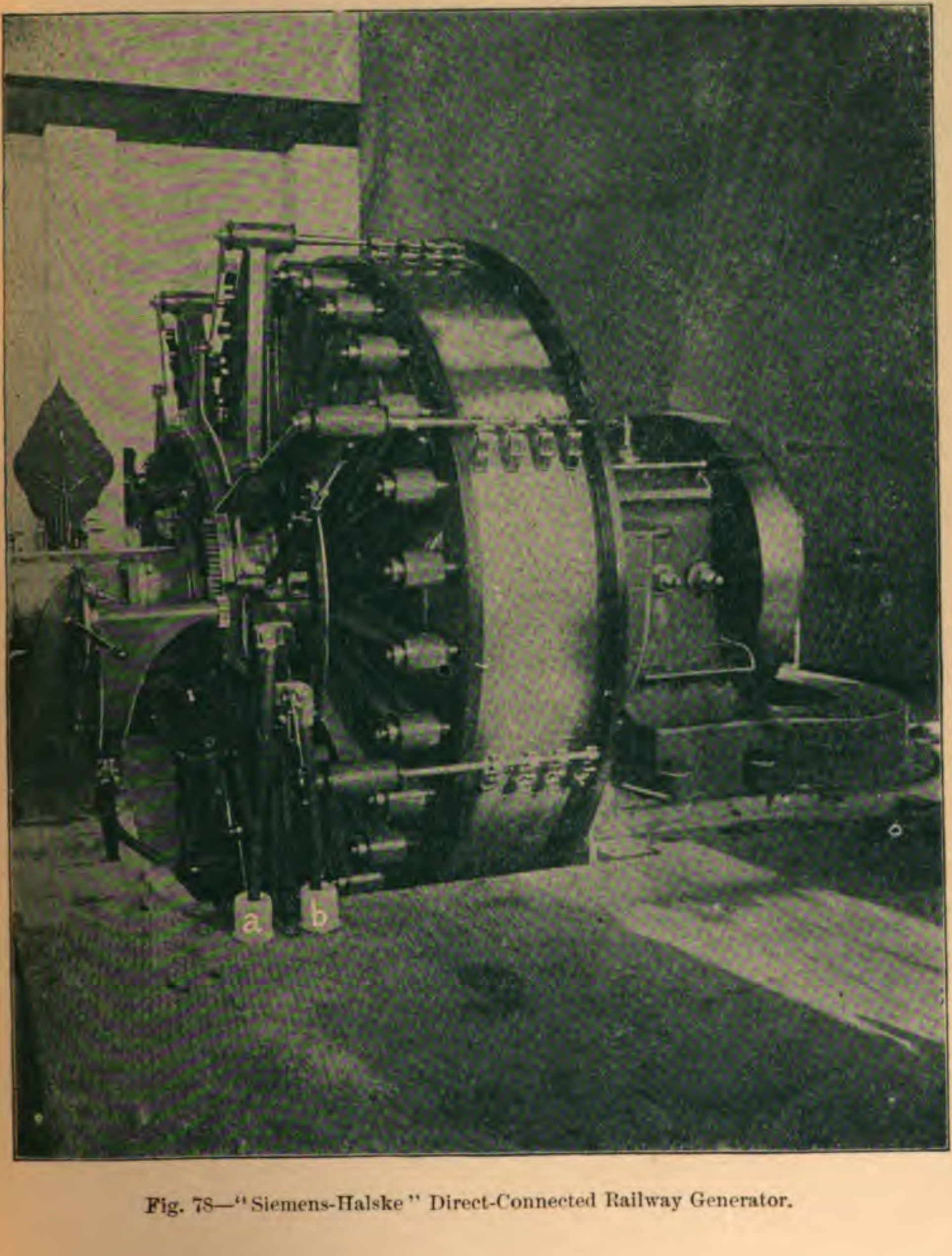


Fig. 78—"Siemens-Halske" Direct-Connected Railway Generator.

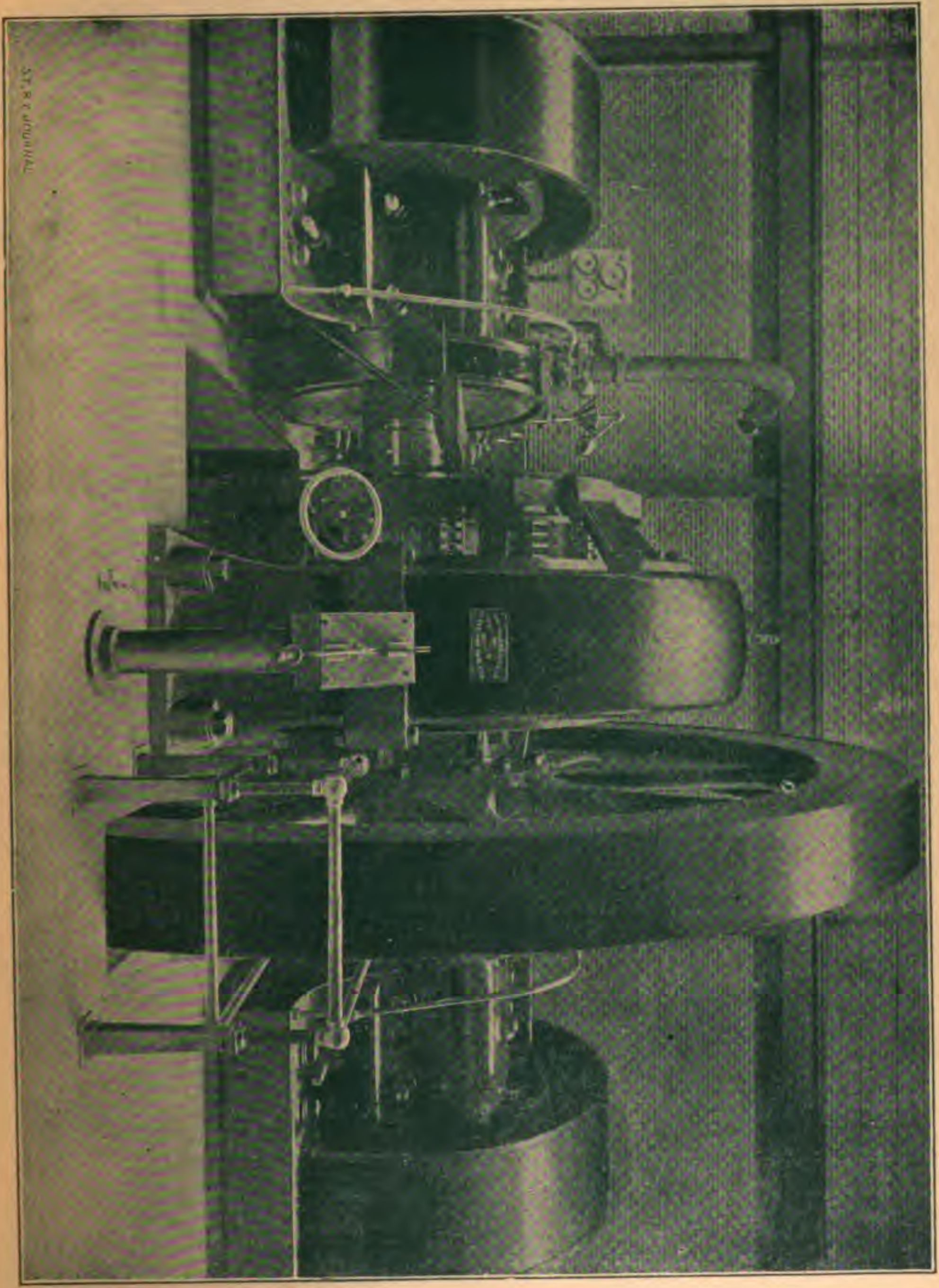


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Fig. 70—Walker Company "Short" Direct-Connected 800 K. W. Railway Generator.

of construction of this machine are represented in Fig. 80. It will be seen that the field frame rests upon two pedestals of masonry, having a pit between them. In this pit descend the field frame and the fly-wheel. 12 sets of four carbon brushes rest upon the commutator, and the brush-holder circle is adjusted by the hand wheel. The armature is barrel-wound, with formed copper bars as represented in Fig. 81. The pole-pieces are formed of laminated iron plates, assembled together as shown in Fig. 82. The yoke is then cast around the dove-tailed projections, so as to hold them securely and effect good magnetic union. A deep slot, as at S, extends through all the plates and, therefore, through the entire pole-

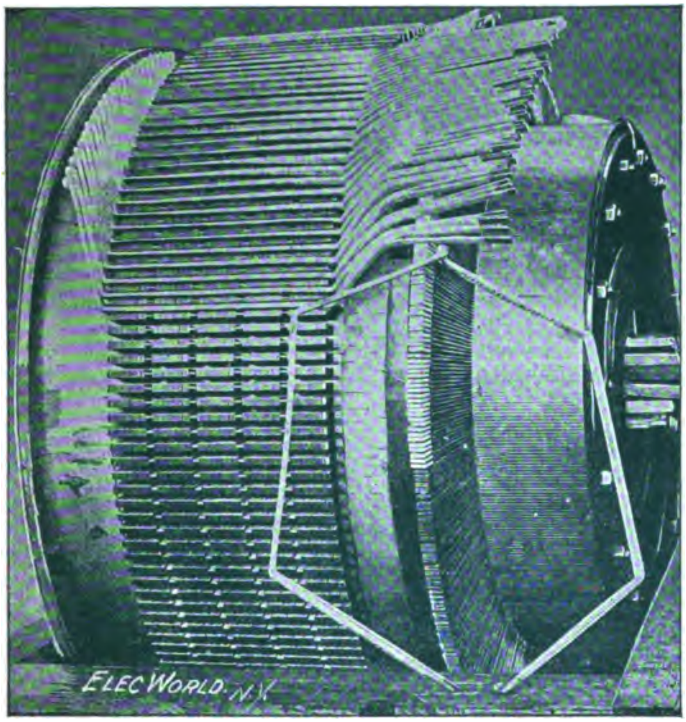


Fig. 81—Walker Company "Short" 800 K.W. Railway Armature Winding.

pieces with the exception of the external plates, for the purpose of preventing an over-crowding of magnetic flux at the forward polar edges. The dimensions of these machines and their foundations is shown in Fig. 83, and its accompanying table in Fig. 83 A.

Fig. 84, shows a General Electric Company's standard 12-pole, 1,300 K. W., 75-revolution, 600-volt railway generator, with the engine and fly-wheel immediately behind it. Here there are 12 sets of 6 brushes resting on the commutator. The copper strips connecting the series windings with the field magnet coils, are visible between the magnetic poles.

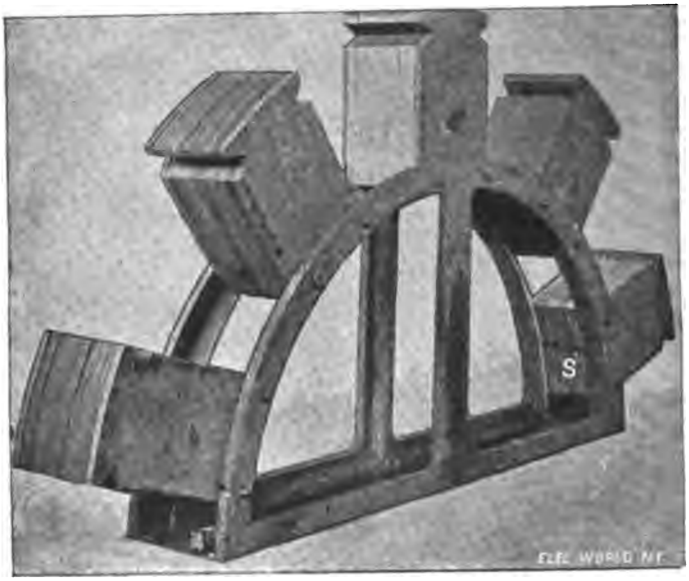


Fig. 82—Walker Company "Short" Assembled Pole Pieces.

Fig. 85, shows with its accompanying table, the dimensions of the General Electric Company's direct-driven railway generators.

POLES	8	8	8	8	8	8	8	8	10	10	10	10	12	12	12	14	14
SPEED REV.	125	200	225	100	150	200	200	300	90	120	90	110	90	80	80	80	75
K W.	100	150	175	200	200	200	250	300	300	400	400	500	800	800	1000	1200	1600
VOLTS	550	550	550	550	550	550	550	550	550	550	550	550	550	550	650	650	650
AMP.	182	273	318	363	363	363	454	545	545	727	727	910	1450	1450	1540	1850	2460
H. P. TO DRIVE	150	220	260	300	300	300	375	430	450	575	600	750	1175	1175	1450	1725	2300
WT. ARM LBS.	7500	7500	7500	13000	9000	8000	8000	8500	25000	26000	31000	32000	42000	46000	58000	71000	80000
TOTAL WT. LBS.	23600	23600	23600	45000	34000	31000	32000	32000	77000	78000	94800	96000	128700	138000	158000	184000	207000
DIAM. SHAFT.	11"	11"	11"	12"	10"	13"	13"	14"	14"	14"	17"	17"	22"	22"	22"	24"	24"
A	91¾	91¾	91¾	105½	97½	92½	92½	92½	141¾	141¾	146¾	146¾	168	168	168	193	193
B	72¼	72¼	72¼	85	81	66⅞	66⅞	66⅞	102⅜	102⅜	107½	107½	122½	122½	122½	146½	146½
C	30	30	30	36	36	24½	24½	24½	37	37	39½	39½	43½	43½	43½	58	58
D	162	162	162	170	162	168	168	168	216	216	216	216	236	236	236	276	276
E	71	71	71	81	68½	78	78	78	121	121	125	125	142	142	142	162	162
F (MIN.)	84	84	84	84	84	90	90	90	96	96	96	96	96	96	96	108	108
G	3½	3½	3½	3½	3½	3½	3½	3½	5	5	5	5	5	5	5	7½	7½
H	72	72	72	72	72	78	78	78	84	84	84	84	84	84	84	96	96
I	107	107	107	129	116	120	120	120	175	175	175	175	195	195	195	228	228
J	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
K	88	88	88	103½	88	94	94	94	144	144	147	147	165½	165½	165½	188	188
L	1¾	1¾	1¾	1¾	1¾	2	2	2	2	2	2½	2½	2½	2½	2½	2½	2½
M	7	7	7	10	7½	6	6	6	13¾	13¾	14	14	14	14	14	8½	8½
N	20	20	20	25	23¾	29	29	29	27½	27½	28	28	32½	32½	32½	26	26
O	20	20	20	25	23¾	29	29	29	27½	27½	28	28	32½	32½	32½	26+26	26+26
P	12¼	12¼	12¼	15½	13¾	13⅜	13⅜	13⅞	18	18	18¼	18¼	20	21	21	23	23
Q	40	40	40	53½	48¼	55	55	55	64	64	65	65	72½	72½	72½	71	71
R	7	7	7	10	7½	6	6	6	13¾	13¾	14	14	14	14	14	8½	8½
S	42	42	42	53	47½	54¼	54¼	54¼	63	63	64	64	71½	71½	71½	70	70

Fig. 83 A—Dimensions of Walker Company "Short" Railway Generators.

A General Electric Company's 12-pole, 1,500 K.W. 75-revolutions-per-minute, 550-volt railway generator, is shown in Fig. 86, directly connected to a vertical type of driving engine. Here, the field frame has a metal cover to protect the armature and carbon brushes from oil.

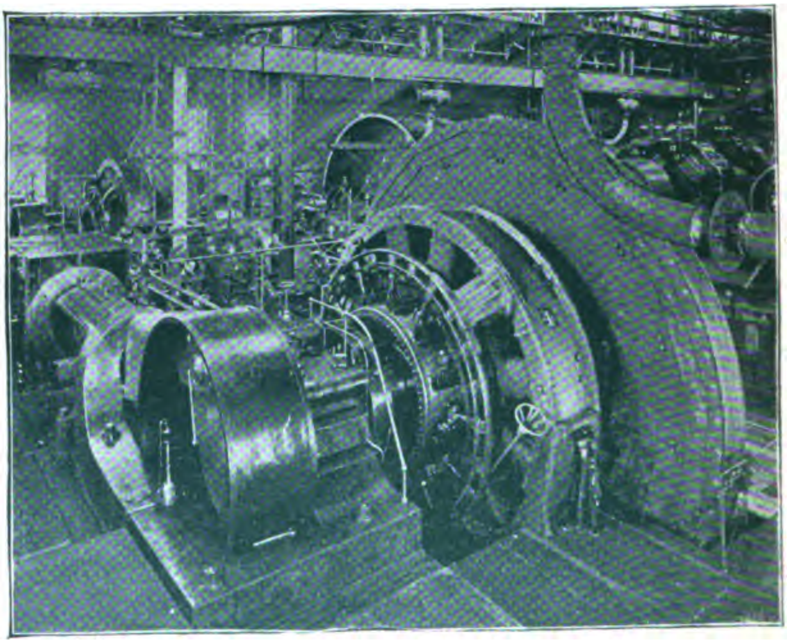


Fig. 84—A "General Electric" 12-Pole 1300 K. W. Railway Generator.

Fig. 87, shows a direct-driven 8-pole, 100 K.W. generator suitable for central-station service on Edison three-wire circuits, supplying a maximum of 140-volts. Such a machine can, therefore, supply about 1,700 16-candle-power incandescent lamps. This machine has no separate commutator but the armature conductors are bared of insulating material on one side of the armature, which is then turned off smooth, so as to form a side commutator. These machines are, as a rule, intentionally not compound-wound, and therefore, are not

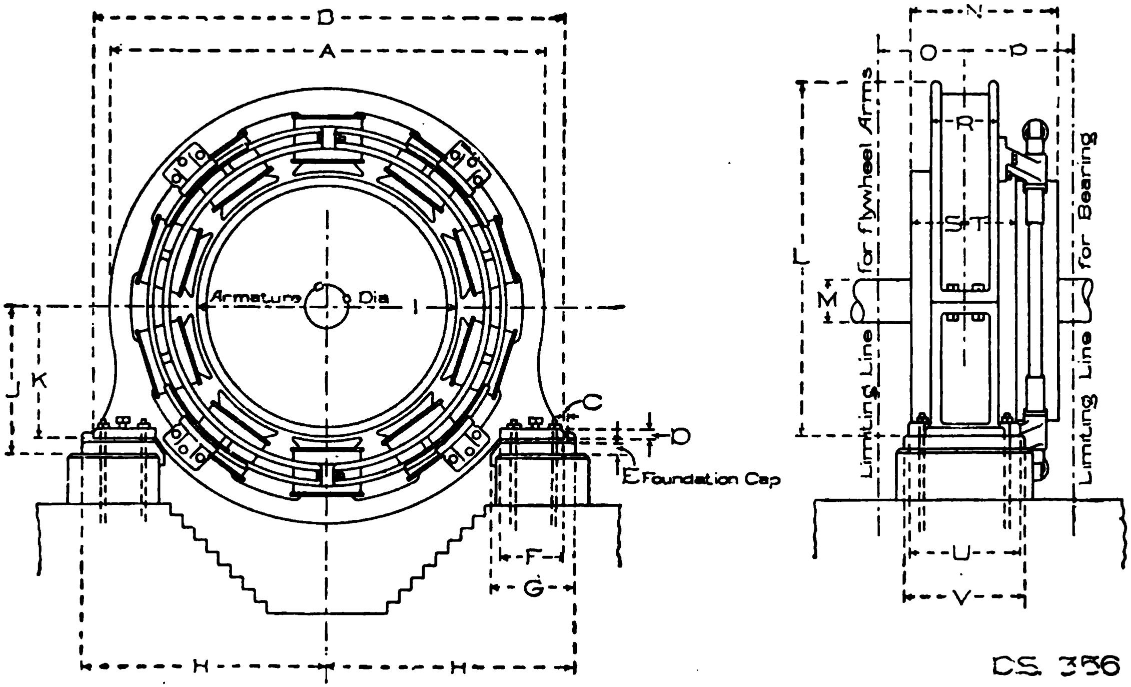


Fig. 85—General Dimensions of "General Electric" Direct-Driven Railway Generator.

GENERAL DIMENSIONS OF DIRECT-DRIVEN RAILWAY GENERATORS. 550 VOLTS.

CLASSIFICATION.				FORM.	Approx. Weight of Armature and Commutator.	Approx. Weight of Generator Complete.	A	B	C	D	E	F	G	H
Type.	Poles.	K. W.	Speed.											
MP	6–	100–	275	F	3,600	10,000	67½	68		2¼		8		34
MP	6–	150–	200	B	6,000	13,000	86⅝	95½	1	3	3	16	22	50¾
MP	6–	175–	200	A	6,500	20,000	95	104	1	3	3	16	22	55
MP	6–	225–	200	D	7,000	21,000	95	104	1	3	3	16	22	55
MP	6–	225–	150	D	13,900	34,300	115½	116	1	3	3	16	22	61
MP	6–	225–	120	D	14,520	37,000	114½	120	1	3	3	16	22	63
MP	6–	325–	150	A	17,000	45,500	111½	120	1	4	3	19	25¼	63
MP	6–	325–	100	A	21,000	61,000	123½	131	1	4	3	19	25¼	68½
MP	6–	425–	150	A	25,500	60,000	118½	134	1	3½	4	22	29	70½
MP	8–	425–	120	A	29,000	65,000	135½	155	1	4	4	24	31	81
MP	8–	425–	100	A	31,000	72,000	136½	155	1	4	4	24	31	81
MP	8–	425–	90	A	32,000	74,000	137¾	155	1	4	4	24	31	81
MP	8–	425–	80	A	32,000	75,000	139¼	155	1	4	4	24	31	81
MP	8–	525–	125	A	31,000	72,000	138	157	1	4	4	24	31	82
MP	8–	525–	100	A	27,000	69,000	138	157	1	4	4	24	31	82
MP	10–	525–	90	A	32,500	76,600	149½	168½	1	4	4	24	31	87¾
MP	10–	525–	75	A	36,000	87,600	151¼	168½	1	4	4	24	31	87¾
MP	12–	850–	120	A	40,000	100,000	167	192	1	5	4	28	35	99½
MP	12–	850–	100	A	44,000	107,000	167	192	1	5	4	28	35	99½
MP	12–	850–	80	A	47,000	116,000	167	192	1	5	4	28	35	99½
MP	12–	1050–	80	A	55,000	130,000	167	192	1	5	4	28	35	99½
MP	12–	1200–	80	A	68,000	158,000	197¾	218	1	5	3	30	37	112½
MP	16–	1600–	75	A	70,000	160,000	194	232	1	5	4	30	37	119½

GENERAL DIMENSIONS OF GENERAL ELECTRIC COMPANY'S DIRECT-DRIVEN RAILWAY GENERATOR.

I	J	K	L	†M	N	O	P	R	S	T	U	V
31¼		23	56	5½-	33½	14¼		14¾	13¾	12	24	
45⅛	36	32	57 7/16	9 -	40½	20	34¼	16	16	14⅞	29	31
45	38	34	81½	9 -10½	43 5/16	19½	33 11/16	17	17½	16	30	33
45	38	34	81½	9 -10½	43 3/16	19½	33 11/16	17	17½	16	30	33
59½	42½	38½	96¼	9 -11½	48½	21¼	88	17½	20¼	18⅛	29	31½
59½	42½	38½	95¾	9 -11½	50½	22¼	89	21	21¼	19⅛	33	35½
53	42	38	92½	11½-14	51½	25	41	25	20⅝	19¼	40	43
59½	46	42	102¾	14 -16	59¾	30	47	25	23¾	22¼	40	43
65½	47½	42½	101¾	14 -16	54⅞	23⅞	44½	25	19⅞	19	40	43
72	47	42	108¾	15 -18	52½	23⅛	41½	21¼	20⅞	19⅝	36¼	39¼
72	47	42	108¾	15 -18	56¼	25	43	25	22¾	21¼	40	43
72	47	42	108¾	15 -18	58¼	26	44	25	23¾	22¼	40	43
72	47	42	108¾	15 -18	59¾	26¾	44¾	25	24½	23	40	43
72	47	42	109½	16 -18	60	25½	47½	25	22¾	21¼	40	43
72	47	42	109½	16 -18	57	24	46	25	21¼	19¾	40	43
88½	49	44	117½	16 -18	54⅜	24	41	22	21¾	20½	40	43
88½	49	44	117½	16 -18	58⅝	25	44	24	23¼	22	40	43
108	57	52	135½	19 -22	49⅝	27	42½	24	17⅞	16	47	50
108	57	52	135½	19 -22	52⅜	27	42½	24	19⅝	17½	47	50
108	57	52	135½	19 -22	57⅝	27	45	29	21¾	20	47	50
108	57	52	135½	22 -	59½	28½	46¼	29	22½	20¾	47	50
126	65	61	159⅞	24 -27	66	28	52¼	31	23¾	21 11/16	49	51
130	53	48	145	24 -27	63¾	29	50	30	23⅞	22 5/16	49	51

† Armature hub can be fitted for either of two sizes of shaft.

self-regulating beyond certain limits. The reason for this is, that the pressure they supply has to be carefully adjusted to to meet Incandescent-Light Central-Station requirements. Their pressure is adjusted by hand with the use of a field rheostat. The brushes, of which there are 8 pairs, are of copper gauze. The brushes are carried on brush-holder arms supported on a circle which is rotated within a limited range by the hand-wheel W, while the brushes can be all lifted or all depressed by the lever L. T, T, are the main terminals of the machine.

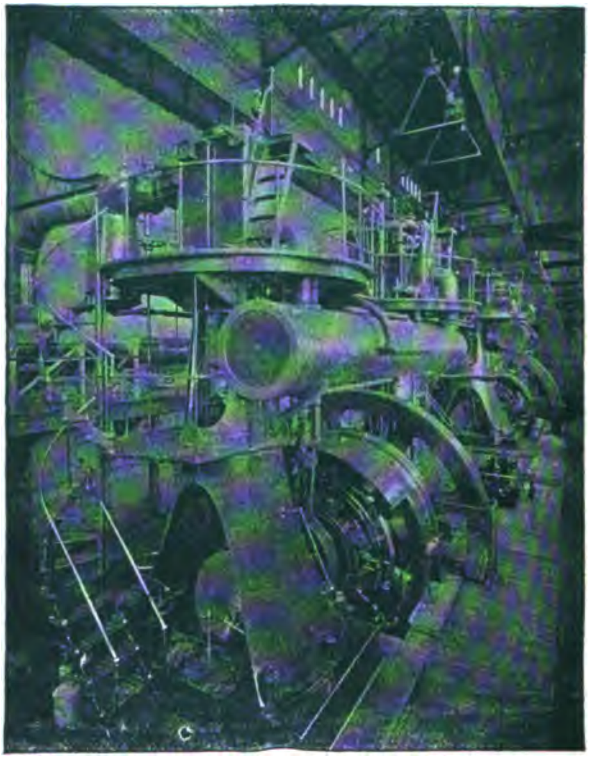


Fig. 86—" General Electric " 12-Pole 1500 K. W. Direct-Driven Railway Generator.

A still more recent type of General Electric Company's smooth-core multipolar Direct-Driven Generator is seen in

Fig. 87 A. This machine is directly connected to a vertical engine and employed for electric railway service.

The generators shown in Fig. 87 and 87 A, are most frequently employed on the Edison three-wire system and are, therefore, usually arranged in pairs, for the reason that in this system the lamps are fed from generators in pairs, connected in series, as shown in Fig. 88, where the generator A, has its negative pole connected to the positive pole of the generator B. The positive pole of the generator A, is then connected to the *positive bus-bar* P, of the station, while the negative pole of the generator B, is connected to the *negative bus-bar* N, of the station. The junction between the two dynamos A and B is connected to the *neutral bus-bar* of the station marked ± in the figure. Under these conditions, if each generator produces at its terminals a pressure of 120 volts, there will be 120 volts between P, and O, and 120 volts between O and N, and, therefore, 240 volts between the outside conductors P and N. The bus-bars are connected to as many pairs of generators in the station as are necessary to carry the load on the system, while the lamps on the system are distributed evenly between the positive and neutral main, and between

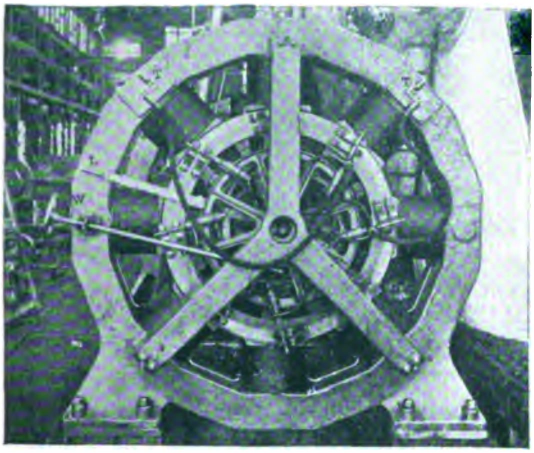


Fig. 87—" General Electric " 8-pole 100 K. W. Direct-Driven Generator for Edison System Incandescent Lighting.

the negative and neutral main, so that the load on the positive generator or generators shall be as nearly equal as possible to the load on the negative generator or generators. Only a comparatively small current returns as an equalizing current to the central station by the neutral conductor.

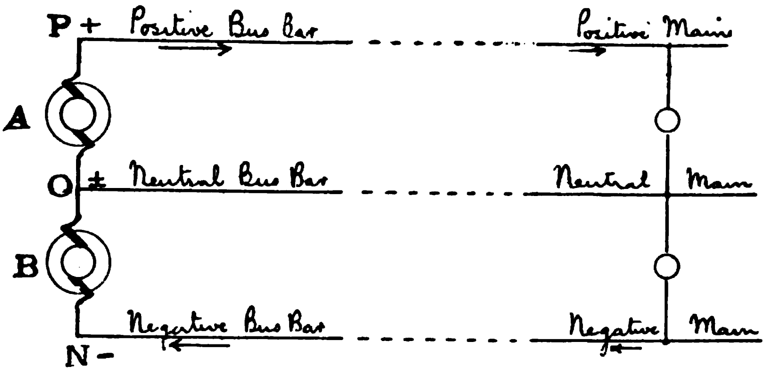


Fig. 88—Connection of Pair of Generators in 3-Wire Central Station.

A pair of 400 K. W. generators of this type, directly connected to a vertical triple-expansion compound-condensing engine is represented in Fig. 89. In order to supply 400 K.W. in each of these two generators, at full load, the engine has to supply 800 K.W. in addition to the electrical losses of the generators, or say 850 K.W. in all. One of these generators is connected between the positive and the neutral busbars, while the other is connected between the negative and the neutral bus-bars, so that both generators are brought into service together, but on opposite sides of the system.

Fig. 90, shows a General Electric Company's 110 K. W. belt-driven generator for 500-volt railway service.

Fig. 91, shows, with the accompanying table, the dimensions of the General Electric Company's belt-driven railway generators.

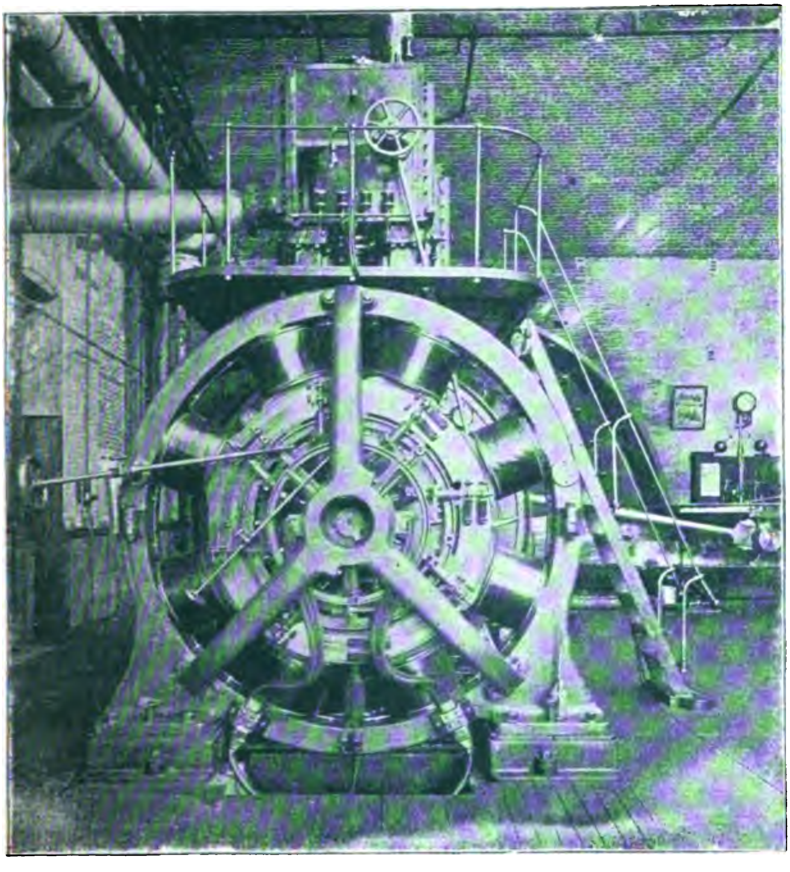


Fig. 87 A—"General-Electric" Company's Direct-Driven Generator.

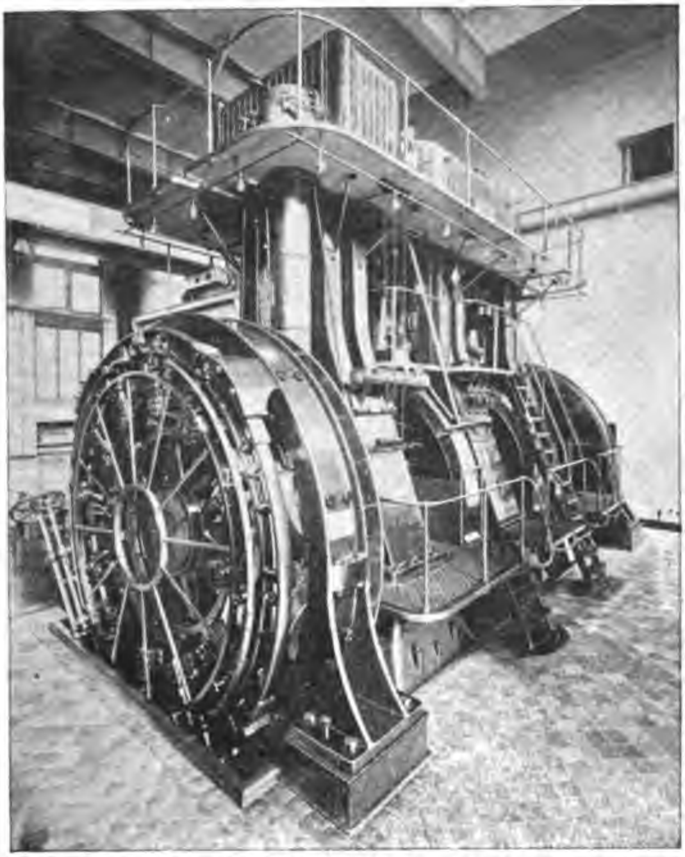


Fig. 89—A "General Electric" Direct-Coupled Pair of Dynamos.

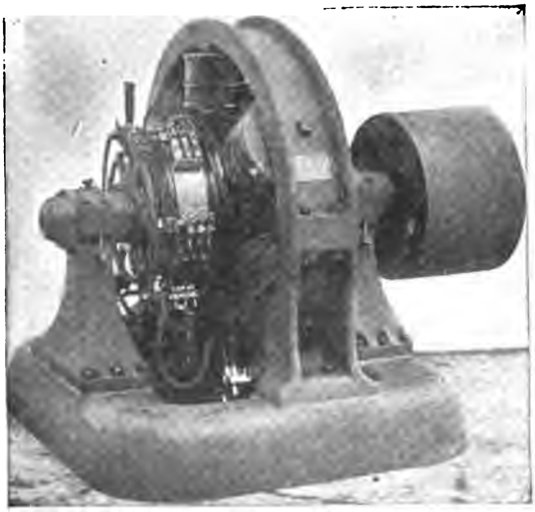


Fig. 90—" General Electric' Belt-Driven 6-110-100 Railway Generator.

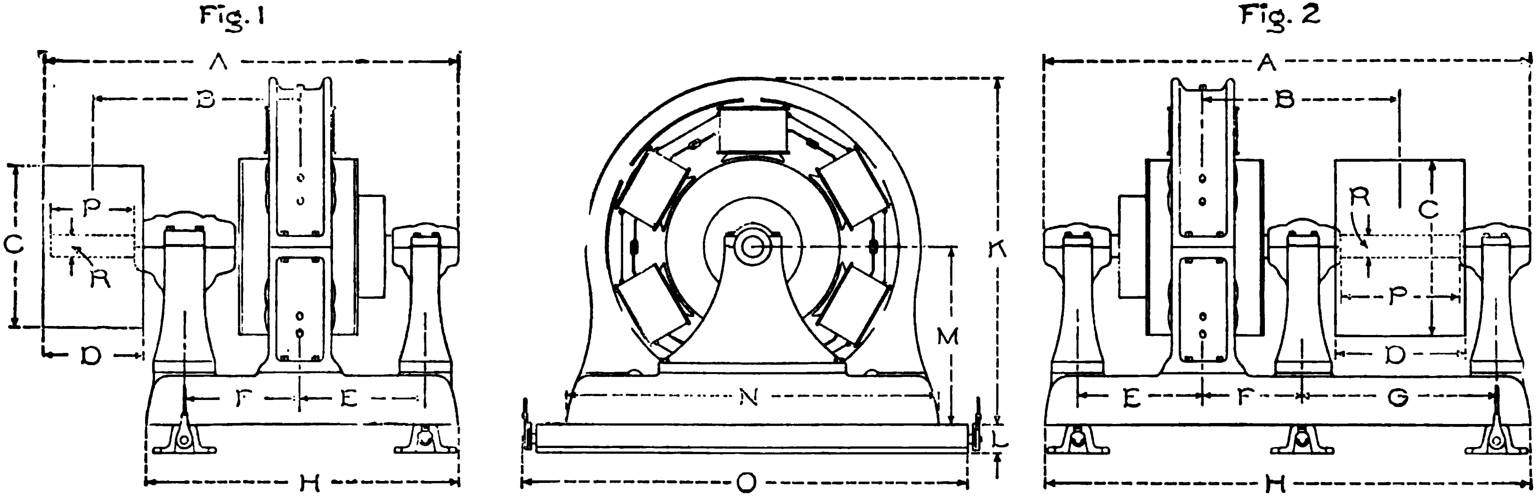


Fig. 91—General Dimensions of "General Electric" Belt-Driven Railway Generators.

TABLE OF GENERAL ELECTRIC COMPANY'S BELT-DRIVEN RAILWAY GENERATORS.

CLASSIFICATION.			WEIGHT.		Fig.	A	B	C	D	E	F	H	K	L	M	N	O	P	R
Poles.	K. W.	Speed.	With Rails.	Without Rails.															
6	110	600	10,000	9,400	1	74½	35	26½	18	23½	18½	56	61¼	2	32	65	77	14⅜	3¾
6	150	400	18,000	17,300	1	89⅛	42¼	44	24	25⅞	20¼	64⅛	71	7	36	71½	87½	$19\frac{9}{16}$	5½
6	225	425	23,000	21,500	1	107	53⅝	41	26	32⅓	29⅞	81	$88\frac{7}{16}$	7	45	95	125½	20⅝	6
6	325	400	38,000	35,000	2	154	63½	43	37	39½	32¾	154	92½	9	47	103	127	35¾	6½
6	500	330	60,500	57,000	2	188½	76	56	56	46	33	188½	107	9	53½	121	146	58	9

It is important that both a railway generator and a central station incandescent generator should have a large reserve of power for occasional overloads. The emergencies which arise both in railroad and lighting service, are such that an overload of 25% may have to be carried for one or two hours. It sometimes happens that a large railway generator carries 50% overload for this length of time, and without undue sparking.

Fig. 92, shows the power house of the Baltimore & Ohio R. R. Co., at Baltimore, Md., with four General Electric Company's 500-K.W. direct-driven railway generators, connected to tandem compound condensing engines, for operating the electric locomotives in the Baltimore tunnel.

Fig. 93, shows a General Electric Company's standard railway switch-board, having six panels, A, B, C, D, E and F. A and B, are generator panels. C, is a collecting panel. D and E, are feeder panels. Two independent generators are connected to A and B, respectively, the A-generator being smaller than the B-generator. Each of these two panels has a pair of main single-pole switches for closing the circuit of the generator, a smaller single-pole switch for closing the field-circuit, and a shunt-field rheostat handle r, for controlling the current strength passing through the shunt-field circuit, and thus regulating the pressure. When the first generator, say connected with B, is brought into action, it is first brought up to speed, then its field switch is closed, allowing the machine to self-excite. The voltmeter V, is then connected with the armature terminals by placing the contact handle *v*, in the B receptacle. This causes the voltmeter V to indicate the pressure generated by the armature. This pressure is adjusted to 500 volts by means of the rheostat r. The two main switches are then closed. The generator is now connected to the bus-bars through the ammeter A′, and the circuit-breaker C, of panel B. If all the *feeders*; i. e. conductors carrying the current to the different sections of trolley wire, are disconnected from the bus-bars, the generator B, does not yet supply any current, so that ammeter A′, still indicates zero. If now the single-pole switch on panel D, is closed, the feeder connected with it is brought into connection with the trolley bus-bar, usually the negative bus-bar. The current from generator B, under full working pressure; i. e. 500 volts, now passes through ammeter A^1, circuit breaker C, to panel C, ammeter A^2, wattmeter W, to panel D, switch, ammeter a, and circuit breaker C, to feeder, returning through the car and by the track or ground feeders.

The two other feeders connected to panel E, are then closed, the current being now distributed to the trolley system through three feeding points. The bus-bar pressure is finally raised to, say 550 volts, in order to maintain 500 volts at the trolley.

When it is necessary to add the other generator A, it is first brought up to speed. The equalizer switch, placed near the machine, and, therefore, not shown on the switchboard, is closed, thereby connecting the series-winding of A, in parallel with the series-winding of B. The circuit breaker C, of panel A, is then closed by hand. The left hand or positive switch S, is then closed, thereby grounding the positive terminal of the armature. The field switch is then closed and the machine allowed to excite, and its pressure is regulated by adjusting the rheostat r, with voltmeter V, and receptacle *v*. As soon as the pressure of A, is practically equal to, or very slightly in excess of bus-bar pressure, say 550 volts, the right-hand or negative main switch S, is closed, thereby connecting the negative terminal of the armature to the trolley bus-bar. Since the armature pressure is almost equal to the bus-bar pressure, very little current flows through machine A. By raising the pressure of A, with rheostat v, some of the load is transferred from generator B, to generator A. Both ammeters a' and A', supply current to the main ammeterA^2, and wattmeter W. Consequently, the sum of the readings of the ammeters on the generator panels A, B, should be equal to the sum of the readings of the ammeters on the feeder panels D, E, and should be indicated on the collecting ammeter A^2. The recording wattmeter W, records the total amount of energy supplied to the system in kilowatt-hours.

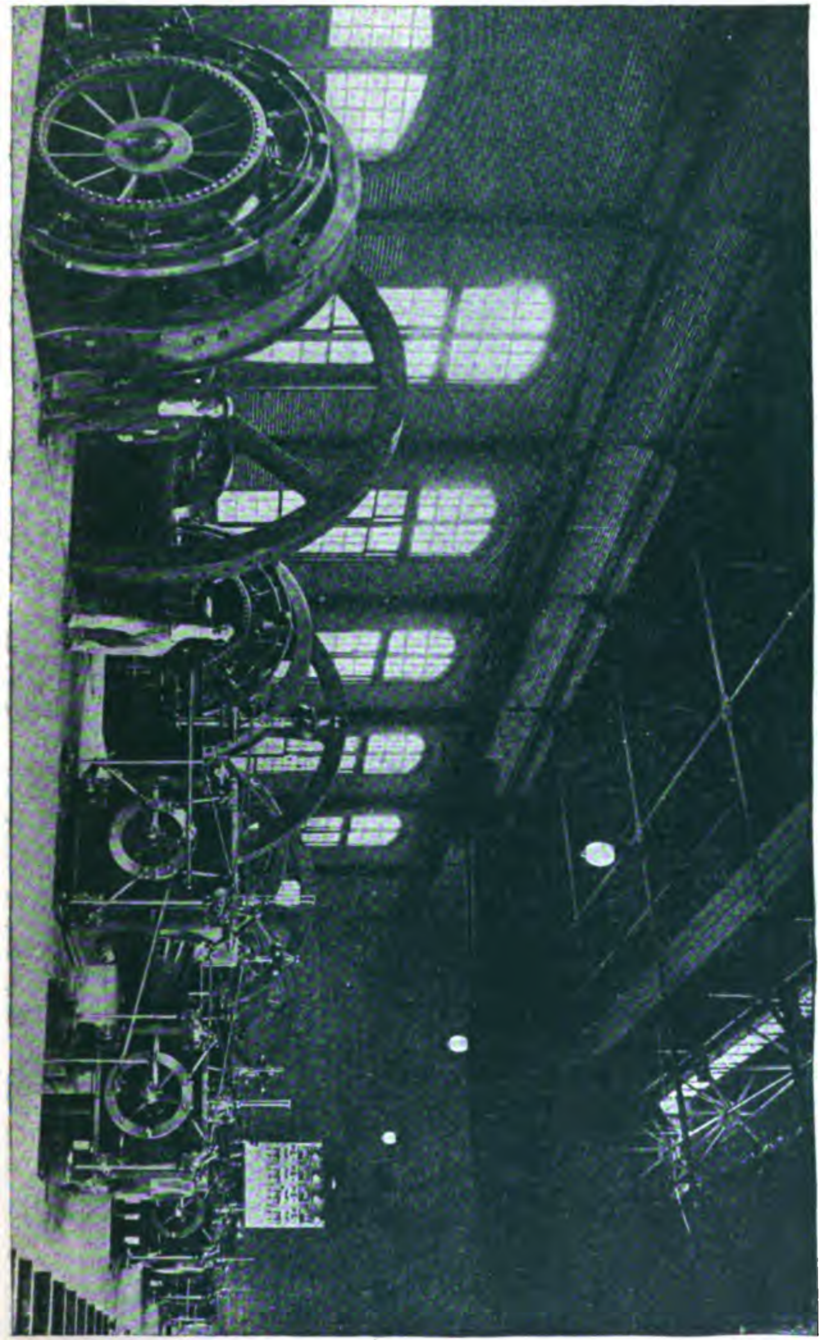
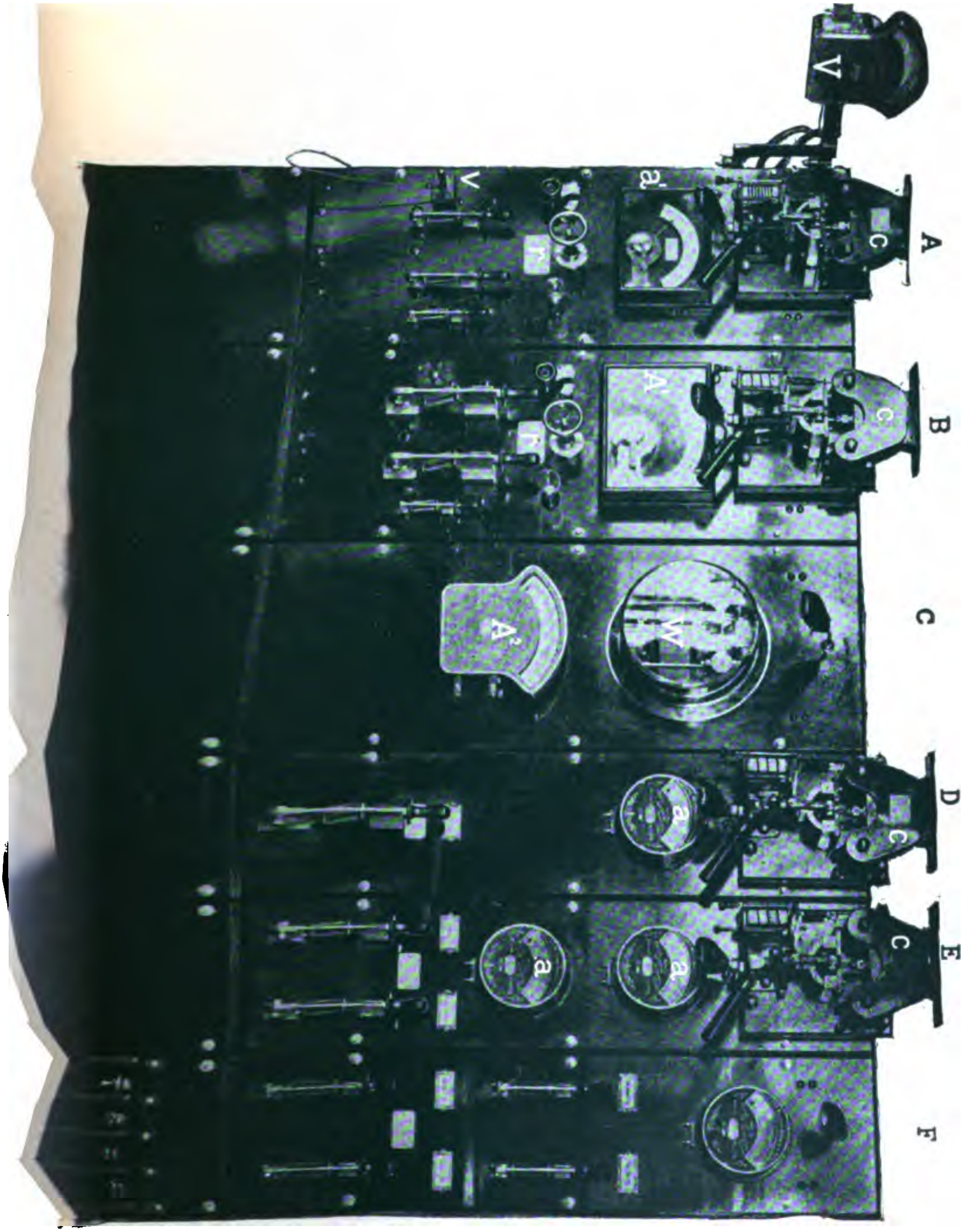


Fig. 92—Power-House of Baltimore & Ohio Railroad Company, Baltimore, Md., with Four 500-Kilowatt "General Electric" Generators.


A
B
C
D
E
F
V
v
a'
c
r
A'
A²
W
a

If either of the generators A or B, should become overloaded, say 75%, the magnetic circuit breaker C, of that panel will release, and open the circuit. Similarly, if a short circuit should occur on feeders D, E, their circuit breakers would automatically disconnect them. Connection at the circuit breaker is re-established by the attendant through the movement of the handle. If a circuit breaker on a feeder repeatedly opens, some fault is indicated, and a repair wagon has to be sent out.

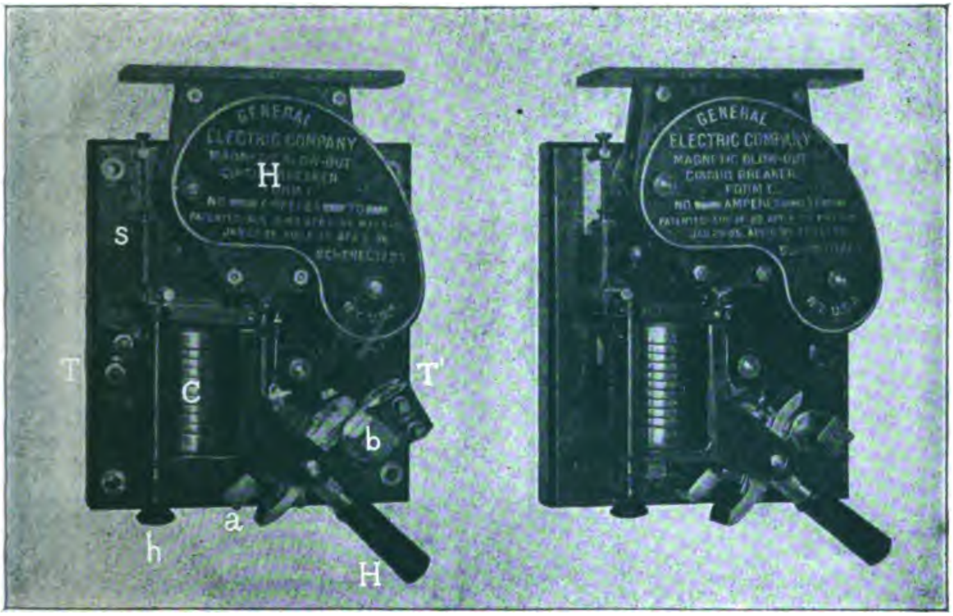


Fig. 94. Fig. 95.

Figs. 94 and 95—"General Electric" Automatic Electric Circuit-Breaker.

The General Electric Company's automatic circuit-breaker is shown in Fig. 94. T, T', are the terminals. The current entering at T, passes around a massive coil C, to the projection a. When the handle H, is set, contact is established between a, and the projection b, of terminal T', through stiff metallic brushes rigidly connected with H. If the current strength becomes excessive, the electromagnetic coil C, attracts the armature over it, against the tension of the spiral spring s. This trips the handle H, and allows it to fly up, thereby interrupting the circuit at *a* and *b*. This would produce a violent flash or arc at these points, if it were not for the fact that an auxiliary contact is maintained in the head H, of the apparatus through a shunt-circuit, for a brief interval after contact is broken at *a* and *b*. The shunt-circuit comprises a pair of electromagnets, so placed that the auxiliary contact breaks between their poles. The arc formed at breaking is thus magnetically extinguished or blown out. The small handle h, is for mechanically tripping the handle H, to open the circuit at will, as well as to test the apparatus, and to see that it is in working order. The auxiliary contact should not break until the main contact is half an inch open.

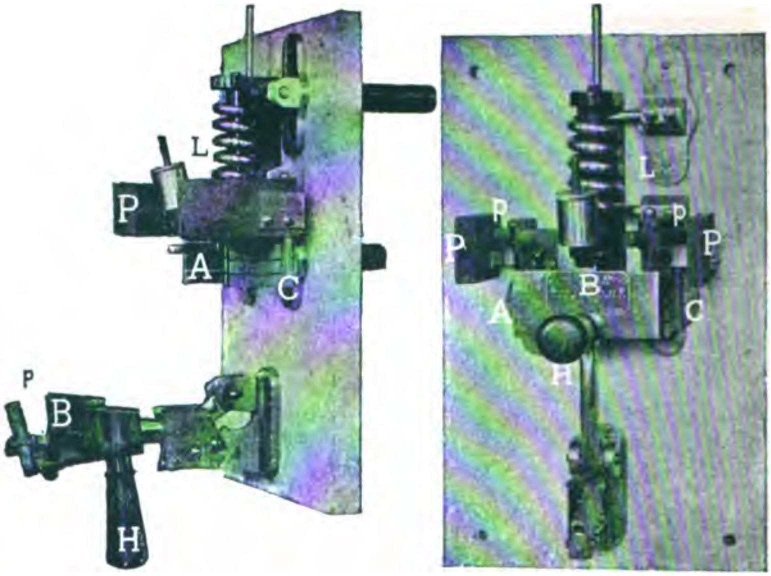


Fig. 96. **Fig. 97.**

Figs. 96 and 97—“ Westinghouse ” Automatic Circuit-Breaker.

The auxiliary contact should be examined from time to time, both to see that it is in good order, and to remove any accumulation of carbonized material. The main contacts at a and b, should also be inspected occasionally.

The form of circuit-breaker shown in Fig. 95, differs only from that shown in Fig. 94, in the fact that the main terminals are brought out at the back of the instrument.

Fig. 96, shows a Westinghouse automatic circuit-breaker open, and Fig. 97, shows the same closed. Here a metallic bridge B, closes a circuit between two clips A and C. When the current becomes excessive, the coil L, included in the circuit, releases a detent allowing the handle H, to fly outwards under the action of a spring. The arc is not formed at the spring clips but at the carbon points and plates p, p, P, P, where the contact is last broken. These carbon points are readily replaced when burned.

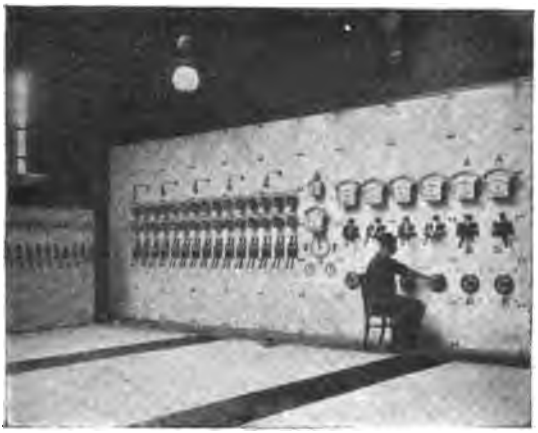


Fig. 98—Part of the Switchboard at a Central Station of the Boston Edison Illuminating Company.

Fig. 98, shows part of the switchboard at a Central Station of the Boston Edison Illuminating Company, as constructed by the General Electric Company. Here, three generating panels are shown on the right-hand side, one collecting panel in the centre, and five feeder panels on the left-hand side. Since the Edison System is a three-wire system, there are, as already explained on page 135, two generators to each unit; so that each generator panel has two shunt rheostats R, R′, two main switches S, S′, and two ammeters A A′.

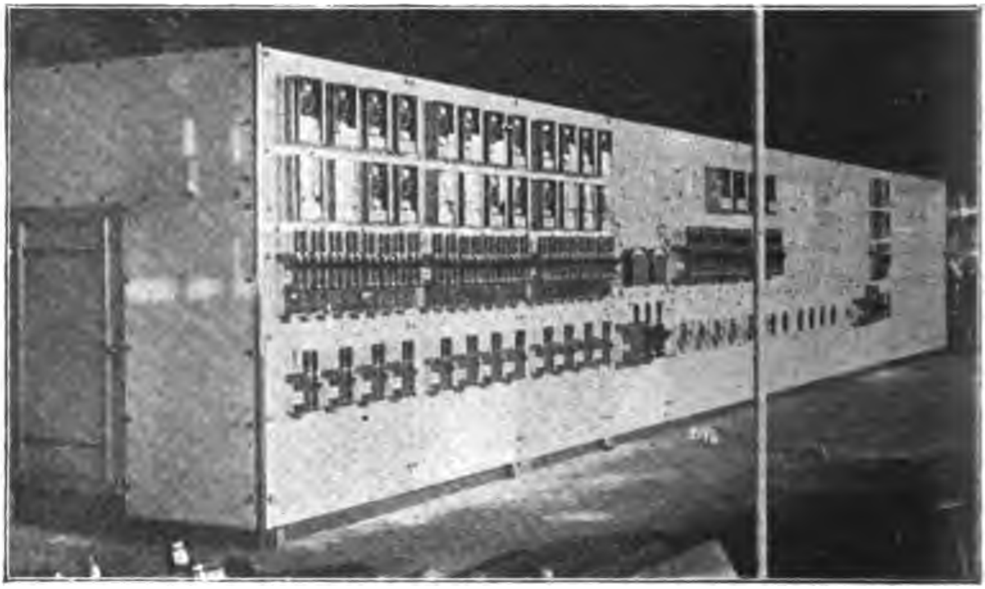


Fig. 99—Switchboard of the Edison Electric Light Company of San Francisco, Cal., built by the General Electric Company.

Fig. 99, shows the switchboard of the Edison Electric Light Company of San Francisco, Cal. This board is nearly 60 feet long, 9 feet wide and 8 feet high. It is a three-wire board, the generating panels being in the centre, and the feeder panels at the ends.

Fig. 99 A, shows a Western Electric Company's switchboard for a large isolated incandescent lighting plant. It has three large panels, the central panel being for the generators, and the outside panels for the distributing circuits. The generator panel has six three-bladed switches, one of which

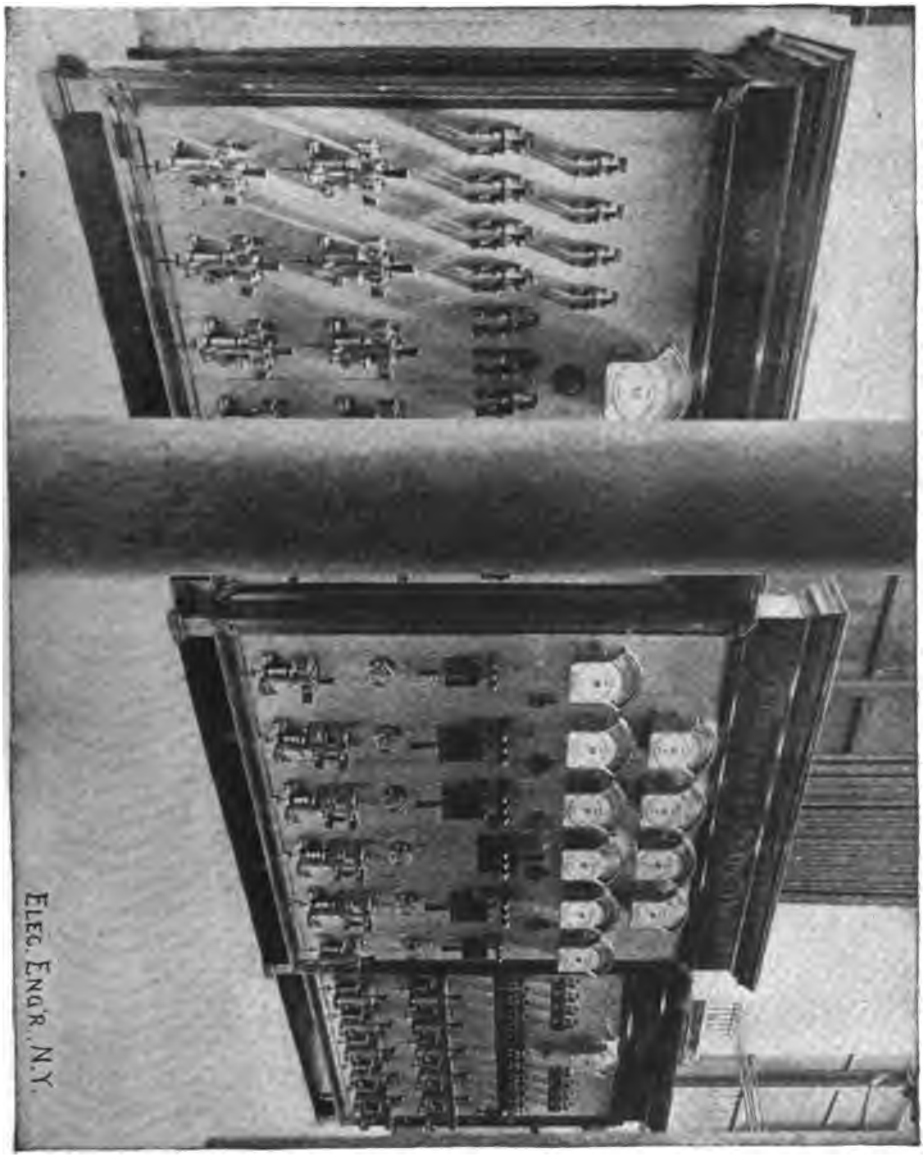


Fig. 90 A—Western Electric Company's Switchboard.

only is closed in the figure. Two of the blades of these switches connect the positive and negative terminals of the generator with the positive and negative bus-bars respectively, while the third blade connects the armature terminal attached to the series coil, with the equalizing bus. Immediately below these main switches, are the circular handles of the generator field-regulator rheostats for controlling the pressure of the generators. Immediately over the main switches, are the generator field-switches, while at the top of the panel are ammeters and voltmeters.

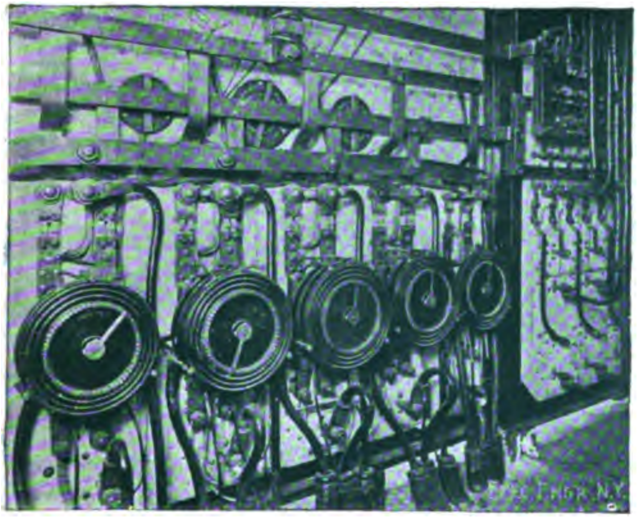


Fig. 99 B—Western Electric Switchboard. (Rear View.)

The back of the generator panel is seen in Fig. 99 B. Here the copper bus-bars are seen at the top. The enamel rheostats for field regulation are supported beneath them.

In operating direct-driven generators it is important that no oil from the engine bearings, or from the engine, should be thrown upon the commutator. Oil guards should be erected where necessary as in Fig. 86. The commutator should always be kept clean and smooth, since any irregularities in the surface tend to grow worse during use. When necessary, a small quantity of vaseline may be applied to the surface of the commutator with a cloth; or, if the surface is rough, it may be smoothed by the application of fine sand-paper, after the brushes have been lifted. If too rough to be cured by this treatment, it should be trued up by a special tool.

CHAPTER V.

CENTRAL-STATION ARC-LIGHT GENERATORS.

MANY arc lamps are operated from constant-potential mains on incandescent lighting circuits, as shown in Fig. 100. Here, P and N, are the positive and negative incandescent mains ; l, l, l, incandescent lamps. A, is an arc lamp suitable for connecting across the mains ; while *a*, *a*, are two arc lamps in series arranged for connection across the mains. Circuits, however, on which arcs are installed solely, almost invariably employ the series connection as represented in Fig. 101, where the current is seen to pass through all the lamps in succession. Since each 2,000 candle-power arc lamp usually requires nearly 50 volts (47), and nearly 10 amperes (9.6) ; or, actually, nearly 450 watts, it is evident that with the series system, the pressure supplied at the terminals of the dynamo must increase by, roughly, 50 volts for every arc lamp in the circuit. In order that a number of series-connected arc lamps shall operate properly, the current which passes through them must be constant. Consequently, the generator must automatically control the current strength it delivers, by increasing or decreasing its voltage according to the number of lamps oper-

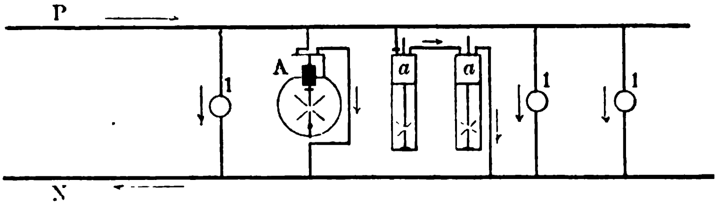


Fig. 100—Arc Lamps Operated from Incandescent Lamp Mains.

ated in the circuit, and their working condition. If an additional lamp should be introduced into the circuit, the tendency would be for the current supplied by the machine to fall. A device connected with the generator, and called the *regulator*, is so adjusted automatically, that as soon as the current commences to fall, it alters the position of the brushes resting upon the commutator, and places them in such a position as to increase the electromotive force or pressure supplied by the machine, and thereby to restore the current strength to its normal amount. In the same way, should a lamp be withdrawn, or the current become excessive from any other cause, the regulator causes the brushes to move over the commutator in the opposite direction, until the pressure generated by the machine has fallen to such a point that the original current strength is restored.

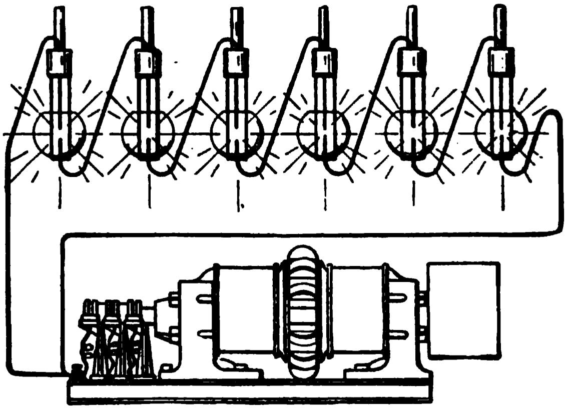


Fig. 101—Diagram of Series Arc-Light Circuit.

Fig. 102, represents a Western Electric 80-light belt-driven arc-light generator. P, is the main pulley which drives the armature. There are two magnet coils M, M, the machine being bipolar, having its two poles at N and S, respectively. Between these poles runs the armature A, with its commutator *c*. A pair of brushes rest on the commutator, one above and one below, opposite to each other. The rocker arm may have its position determined either by hand, under the influence of the handle H, or, as is usually the case, automatically under the control of the regulator R.

The regulator is an electromagnetic mechanism placed in the main circuit of the generator, and, therefore, traversed by the total current, which should be maintained at, approximately, 10 amperes. The regulator is mechanically operated by a small belt running from the pulley *p*. If the current strength is normal, the regulator remains idle, but if the current should increase, the rod R, is caused to move in the opposite direction and thereby to rotate the rocker arm into a more nearly horizontal position. When the brushes are nearly vertical, the generator delivers its minimum voltage, which is only a few hundred volts. The machine, there-

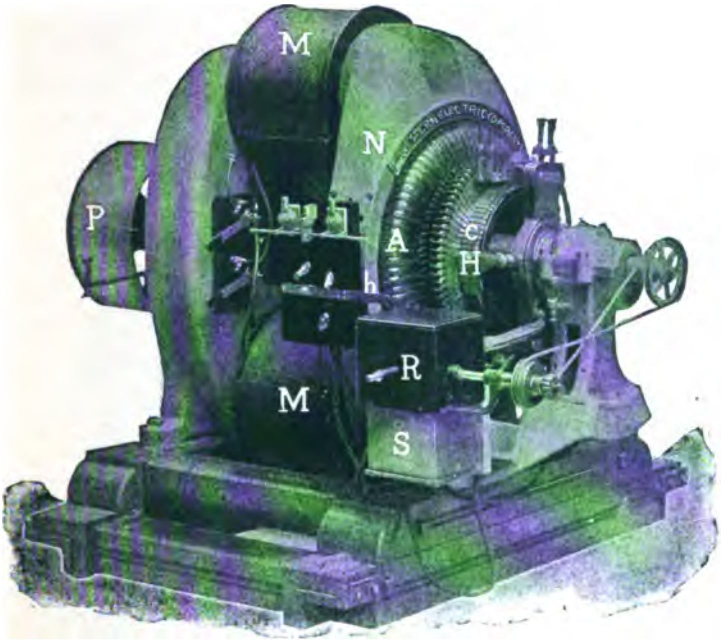


Fig. 102—Western Electric Type F, Arc-Light Generator.

fore, always adjusts automatically for constant current, which is usually nearly 10 amperes, (9.6). The main terminals are led to the arc-light circuit, through the switch-board. Between them is a *lightning arrester*, or a device for protecting the field and armature coils from the high pressure of a lightning discharge. It consists of a pair of carbon points, situated opposite a vertical carbon plate, which is connected to ground. Should a lightning discharge occur between one of the main terminals and the grounded plate, thereby establishing an arc, this arc would be promptly blown out, or extinguished, by the magnetic field in the neighborhood of the pole-piece N, upon which the arrester is mounted.

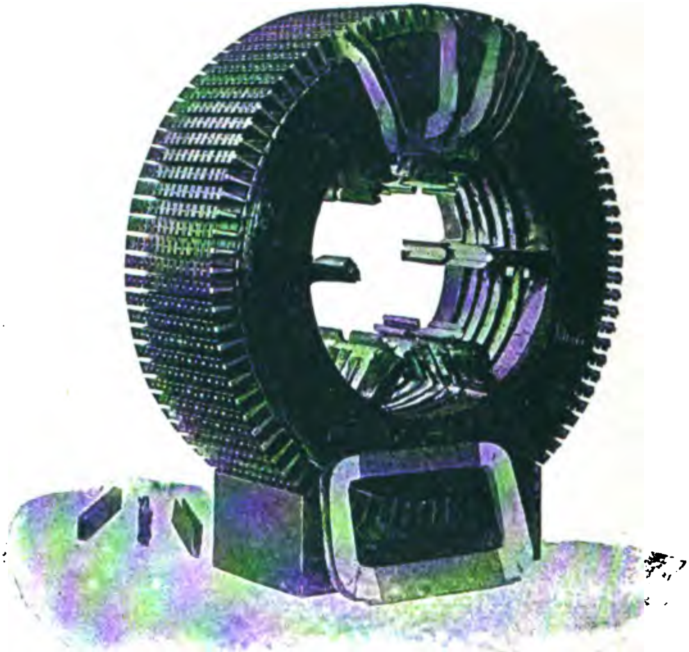


Fig. 103—Armature Core of "Western Electric" Arc Generator ready for Winding.

The main switch h, in the position shown, short-circuits both field magnets and armature, so that no current is delivered by the machine to the external circuit when the armature is rotated while in this position. On lifting the switch lever, the short-circuits are removed and the machine is ready to operate. On the yoke, are two *reducing switches*, for varying the power of the magnets. By closing one switch, the machine is enabled to run on comparatively unsteady loads, with a somewhat longer spark than usual at the brushes. By closing the other switch, the regulator can be adjusted to control for a reduced current strength, so that the machine may be operated at a reduced current.

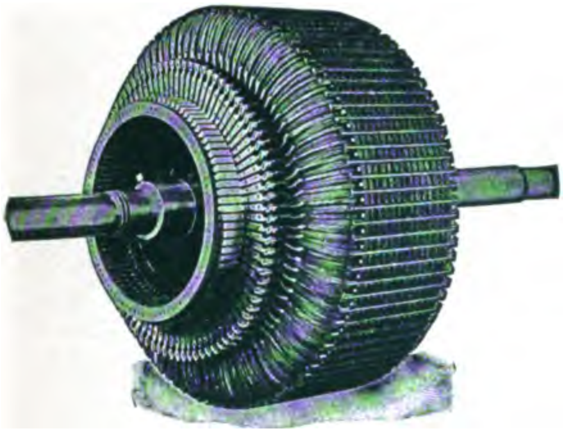


Fig. 104—Complete Armature of "Western Electric Arc Generator.

This is often a convenience, since 2000 candle-power lamps can be operated at 1200 candle-power after midnight in many places.

The armature core of the preceding machine is shown in Fig. 103, ready for winding. It consists of a laminated structure, made up of thin punched plates, so assembled as to leave ventilating spaces extending circumferentially around the core. The coils are wound in troughs of pressed board, oiled paper, and mica, slipped into the grooves. Fig. 104, shows the complete armature from the commutator end. The winding of the armature is that of an ordinary Gramme-ring, as represented in Fig. 68, and the junction of each pair of coils is brought to a commutator segment. If any discontinuity should occur in one of the coils, that coil may be disconnected from the commutator, and the gap at the commutator bridged over by a *jumper*, without sensibly affecting the operation of the machine. The armature is supported on

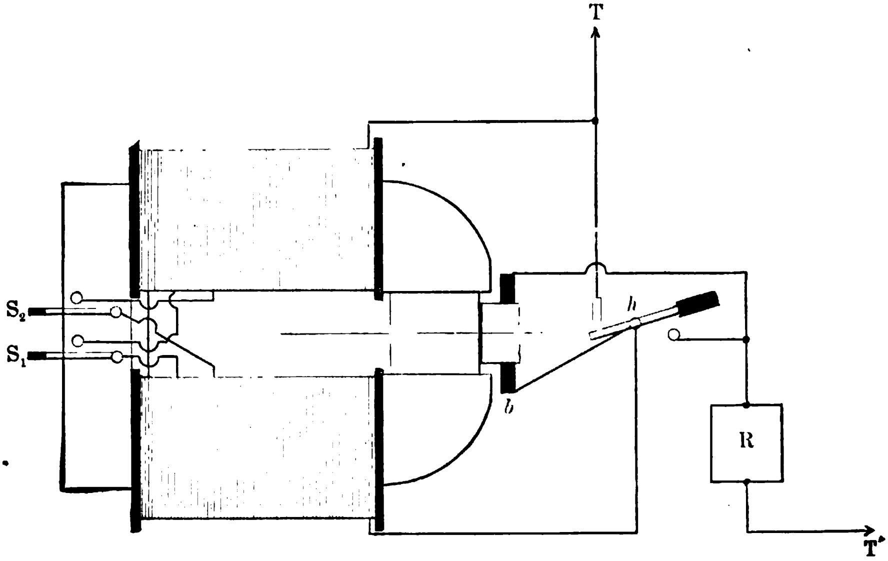


Fig. 105.

a brass spider, so arranged as to facilitate ventilation, by throwing air through the armature under centrifugal force, during rotation.

The armature is devoid of band wires, since the coils are laid in their slots and held in place against centrifugal force by insulating wires driven in at the top. This facilitates the examination and repair of the armature coils. In order to remove a damaged coil, the armature can be slid out of the field and rested in the bearing seat. The commutator is then unscrewed and removed, giving immediate freedom to the coils.

A sketch of the connections of this machine is given in Fig. 105.

Commencing at the lower or positive brush b, on the commutator, the current flows to the centre of the switch h. When this switch is in the working position shown, it passes around the field coils and to the external circuit by the positive terminal T. It returns by the negative wire to the terminal T′, through the regulator, and completes the circuit through the upper commutator brush. When the switch h, is pressed down, it first short-circuits the field coils and then the armature. The connections of the reducing switches are shown on the left-hand side of the figure. When both reducing switches are open, the current flows through all the turns of the field coils, so that the field magnets have their maximum strength. Closing the lower switch, short-circuits some of the turns on both coils; namely, those nearest the yoke. Closing the upper switch, short-circuits more of the turns on both coils; namely, those between the yoke and the second taps. These switches, therefore, serve to weaken the field magnets.

When the armature has to reverse its direction, the armature terminals have to be reversed.

The general dimensions of these belt-driven machines are given in the accompanying table:

It will be seen that the machines in this table are rated for both 2,000-candle-power arc lamps, taking 9.6 amperes in the circuit; and for 1,200-candle-power arc lamps, taking 6.8 amperes in the circuit, so that a machine of the size capable of supplying fifty 2,000-candle-power arc lamps, can supply seventy 1,200-candle-power arc lamps. These machines are also wound for six amperes for use with long burning, enclosed arc lamps, and the large dynamos are wound for two circuits in cases where the voltage would otherwise be too high. A 50-light Western Electric Generator, direct-connected to a Willans engine, is represented in Fig. 106.

A Wood arc-light generator, capable of supplying eighty

TABLE OF DIMENSIONS OF WESTERN ELECTRIC COMPANY'S ARC-LIGHTING DYNAMOS.

			2000 C. P.			1200 C.P.			Pulley.			General Dimensions.			Approximate Shipping Weights.	
	Number.	Type.	Lamps at 9.6 Amps.	Volts.	Approximate Speed.	Lamps at 6.8 Amps.	Volts.	Approximate Speed.	Diameter.	Face.	Width of Belt.	Height from Floor to Centre of Shaft.	Total Height.	Floor space over all (First Dimension Parallel to Shaft.)	Armature.	Dynamo Complete.
Surface Wound Armatures.	1	F	60	3300	775				Ins. 18	Ins. 11	Ins. 10	Ins. 32½	Ins. 58¾	Ins. 72¾ × 62	1150	7600
	2	4 P	100	5500	500				30	14	13	37¼	64	74½ × 74	1900	10700
	3	4 P	125	6500	500				30	16	15	37¼	64	77½ × 74	1900	10700
Ironclad Armatures.	4	I.C.F.	50	2750	1000	70	4125	1000	14	10	9	27	49	64⅝ × 65⅝	800	5000
	5	I.C.F.	60	3300	925	80	4400	950	18	10	9	28	50	65½ × 65⅝	900	5400
	6	I.C.F.	80	4400	775	100	5500	750	19	13	12	34¼	61¾	$78\frac{13}{16}$ × 67	1380	7500
	7	I.C.F.	100	5500	650				24	14	13	36	67	86½ × 70½	1630	9300
	8	I.C.F.	125	6850	500				30	16	15	37¼	72½	94⅝ × 75	2000	11500

2,000-candle-power arc lights, and delivering 9.6 amperes at a terminal E. M. F. of 4,000 volts, at a speed of 875 revolutions per minute, is seen in Fig. 107. This is a bipolar belt-driven machine with four magnet coils M, M, M, M, through which the current passes from the armature to the series arc-

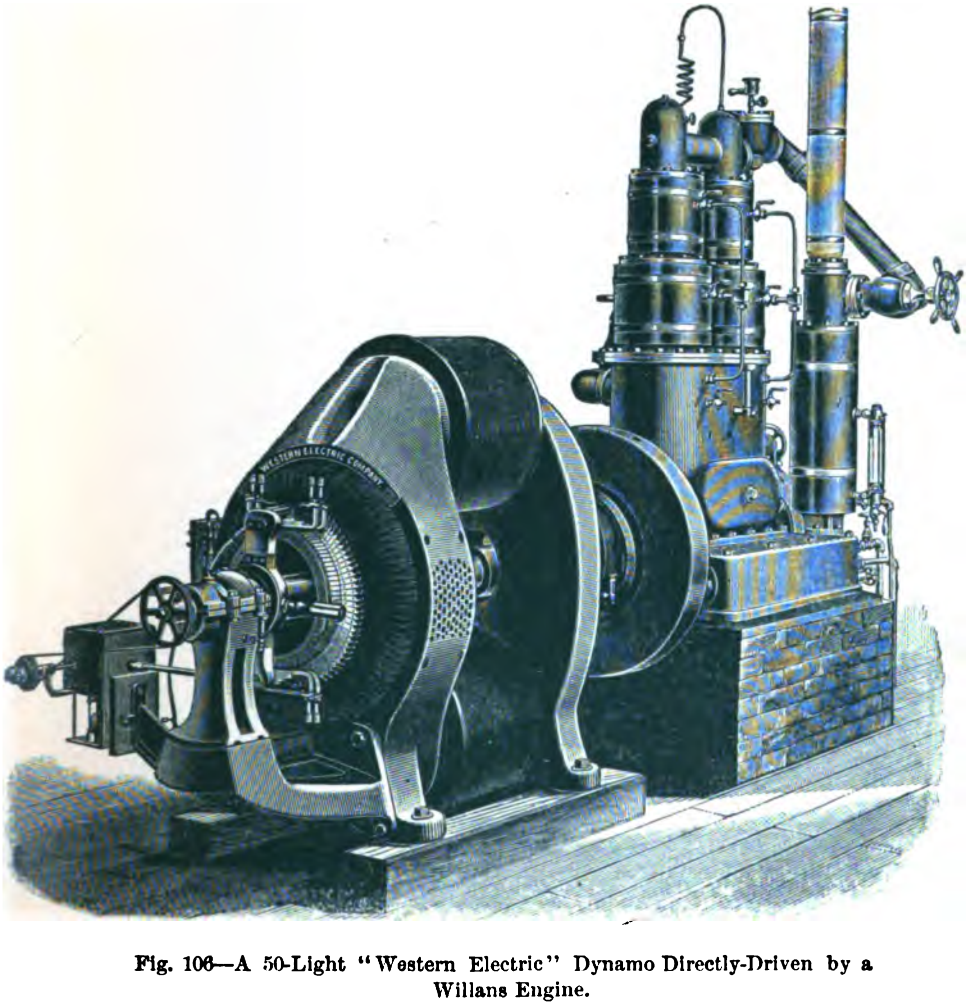


Fig. 106—A 50-Light "Western Electric" Dynamo Directly-Driven by a Willans Engine.

light circuit. The current passes in such a direction as to produce, say a north pole at N, and a south pole at S. There are two sets of copper brushes, each set consisting of two separate brushes inclined at a small angle to each other. The main current passes through the regulating magnet m, which is thereby caused to attract its armature against the tension of the spiral spring s. If the current in the circuit exceeds 9.6 amperes, for which the machine is adjusted, the magnetic attraction so far exceeds the tension of the spring, as to move

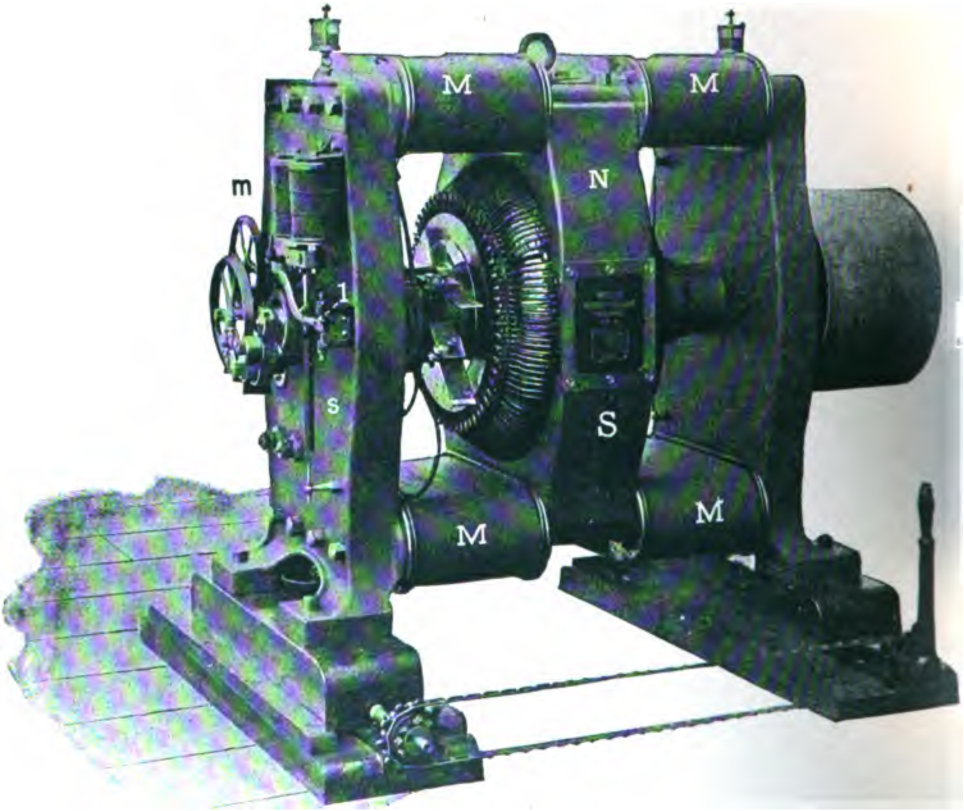


Fig. 107—A "Wood" Arc Light Generator for 80-Lights 2000 Candle Power.

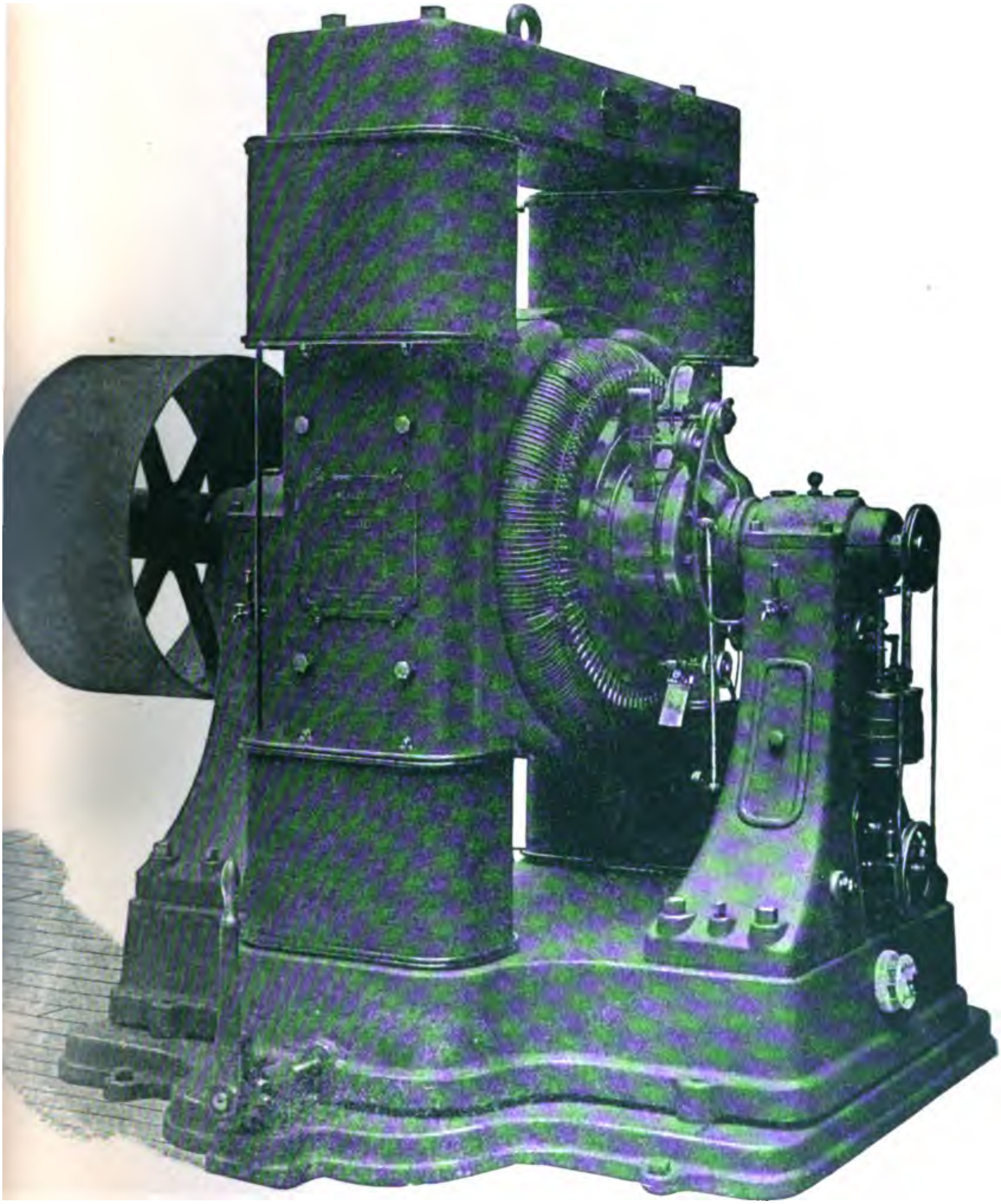


Fig. 108—"Wood" Vertical 125-Light Belt-Driven Generator.

DIMENSIONS OF BELT-DRIVEN WOOD ARC-LIGHT GENERATORS WOUND FOR 4.25, 6.8 AND 9.6 AMPERES.

No. of Dynamo.	No. of Lights.	Nominal C. P. 4.25 Amp., 45 to 50 Volts.	No. of Lights.	Nominal C. P. 6.8 Amp., 45 to 50 Volts.	No. of Lights.	Nominal C. P. 9.6 Amp., 45 to 50 Volts.	Horse-power Required.	Diameter of Pulley.	Face of Pulley.	Width of Belt.	Revolutions per Minute.	Height from Floor to Centre of Shaft.	Total Height.	Floor Space in Inches. First Dimension Parallel to Shaft.	Weight of Armature.	Weight of Dynamo, Complete.	No. of Dynamo.
1					1	2000	1½	3½	2¼	2	1600	11	16	19 x 27	44	160	1
2					1	6000	3	5	3½	3	1250	13	20	24 x 27	85	300	2
2			4	1200	3	2000	3	5	3½	3	1450	13	20	24 x 27	85	340	2
3			9	1200	6	2000	5½	6½	4½	4	1300	16	25	30 x 32	128	600	3
4	20	800	15	1200	10	2000	9	8	5½	5	1150	18½	29	38 x 32	190	1000	4
5	35	800	25	1200	15	2000	13	10	6½	6	1075	21⅛	35	41 x 38	247	1500	5
6	60	800	35	1200	25	2000	20	12	8	7	1000	24⅛	40	48 x 43	325	2100	6
7	90	800	50	1200	40	2000	30	14	9	8	925	26⅛	45	52 x 43	469	2900	7
8			75	1200	60	2000	42	16	10	9	900	29¼	50	58 x 49	605	3900	8
9			100	1200	80	2000	56	18	12	11	875	31⅝	54	62 x 49	808	5200	9
10					125	2000	90	32	15	14	500	45⅞	91	82 x 80	2200	14600	10

the lever l, upwards, and engage wheel work with the revolving armature in such a manner as to cause the brushes to be moved to a more nearly vertical diameter on the commutator, or into a position of weaker voltage. If, on the contrary, the current strength becomes too weak, the spiral spring s, pulls down the lever l, and causes the brushes to be moved in the opposite direction, or towards a more nearly horizontal diameter, where the voltage is more powerful. The accompanying table gives the dimensions of these machines.

Fig. 108, shows a Wood vertical 125-light belt-driven generator, intended for the delivery of 9.6 amperes at 6,250 volts and 500 revolutions per minute. Its efficiency is 90% at full load, and its full-load temperature elevation is 40°C.

Here the magnetic field is of the same type as in the last machine described (Fig. 107) but is set vertically instead of horizontally, the pole piece nearer to the observer being, say, of north polarity, and the other of south polarity.

Fig. 109, shows the connections of one of these vertical generators. Starting from P, the positive pole of the machine, connected to the positive pair of brushes on the commutator, the current passes to the switchboard Sw, thence to the lightning protector L_1, and to the arc lamps in series along the line l_1. After passing through all the arc lamps, the current returns by the line l_2, through the lightning-arrester L_2, the switchboard Sw, to the negative terminal N ; from thence it passes through two left-hand field-coils on the magnet N, and coils of the magnet S, through the windings of which it descends. The current then passes through the regulator magnet m, and enters the armature at the lower pair of brushes. The switch C, on the base of the machine, serves to short-circuit the field-magnet coils, under which condition the armature fails to generate voltage and, therefore, the machine ceases to operate.

A direct-driven 100-light, Wood arc-light generator is shown in Fig. 110. This machine delivers 9.6 amperes at a pressure of 5,250 volts, and is coupled to a 90 H. P. compound engine, making 460 revolutions per minute.

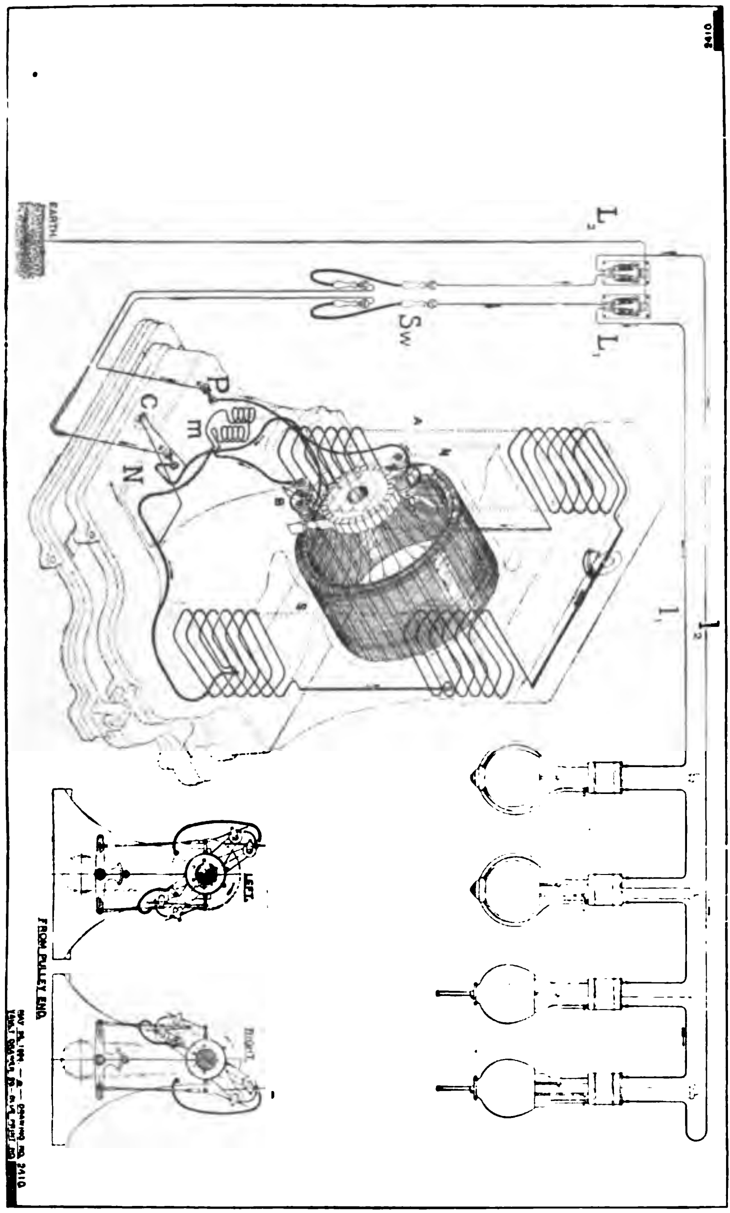


Fig. 100—Connections of Vertical Type "Wood" Arc-Light Generator.

Fig. 111, shows an Excelsior Electric Company's constant-current belt-driven arc-light generator for one-hundred 2,000-candle-power lamps. It is a bipolar machine, one pole being above, and the other below the armature. The pole pieces are hinged in such a manner as to readily permit the front portions to be moved away and leave the armature in full view, as shown in Fig. 112. The current from this machine is maintained constant, by causing the brushes to be automatically shifted by means of a small motor, which is brought into play by a regulating magnet placed in the main circuit. If the current is too strong, the motor is started in one direction, while if the current is too weak, the motor is started in the opposite direction. This motor, which is supported within the projection on the bracket bridging the two pole-pieces, performs two functions. It rotates the rocker arm which carries the brushes, and also, through the movements of the rod, cuts in or out, sections of the field-magnet coils which

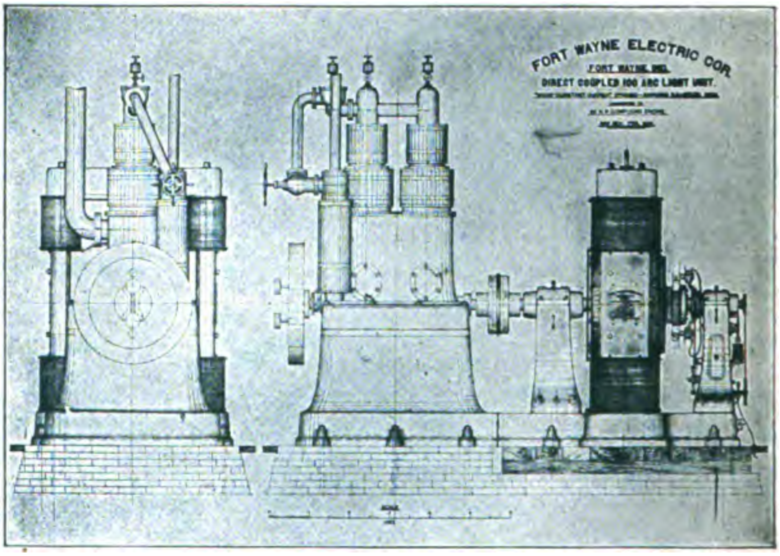


Fig. 110—Direct-Driven "Wood" Arc-Light Generator.

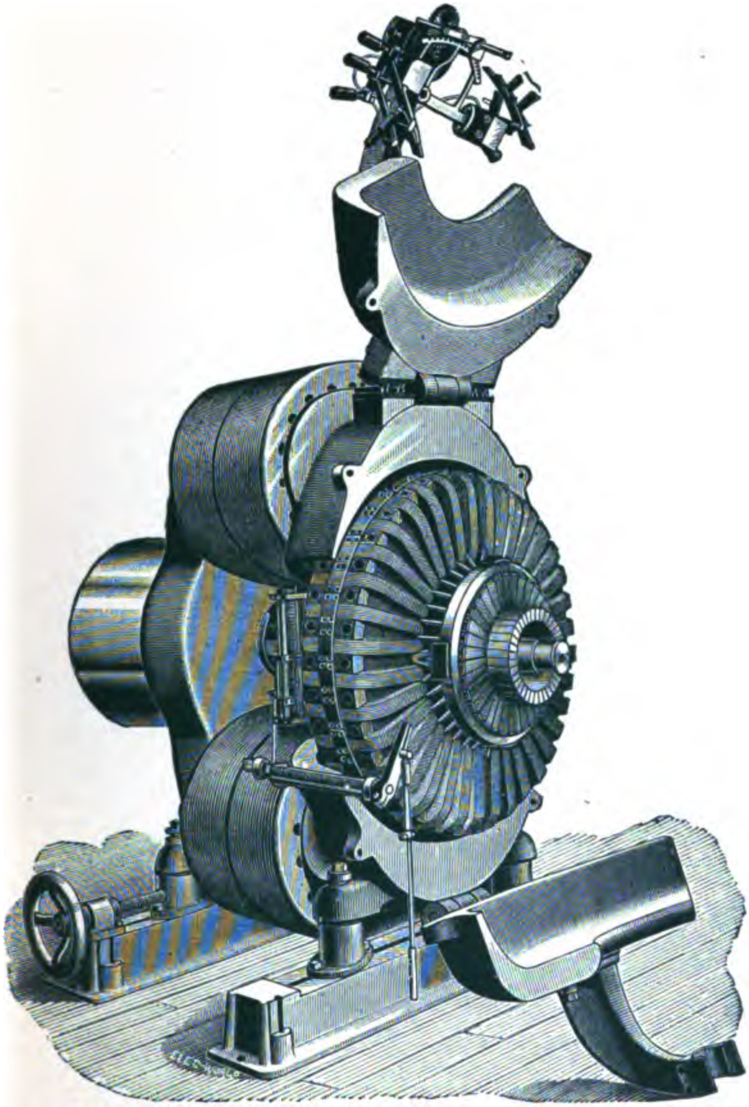


Fig. 112—"Excelsior" Belt-Driven Arc-Light Generator with Hinged Pole-Pieces, turned out, exposing Armature.

are in the main circuit. If the current strength becomes excessive, the motor shifts the brushes, and also reduces the excitation, or number of ampere-turns on the field magnets, thereby tending to reduce the voltage; while, on the contrary, if the current strength becomes too weak, the motor moves the brushes into a position of greater voltage, and at the same time increases the excitation of the field magnets, thereby tending to increase the generated voltage.

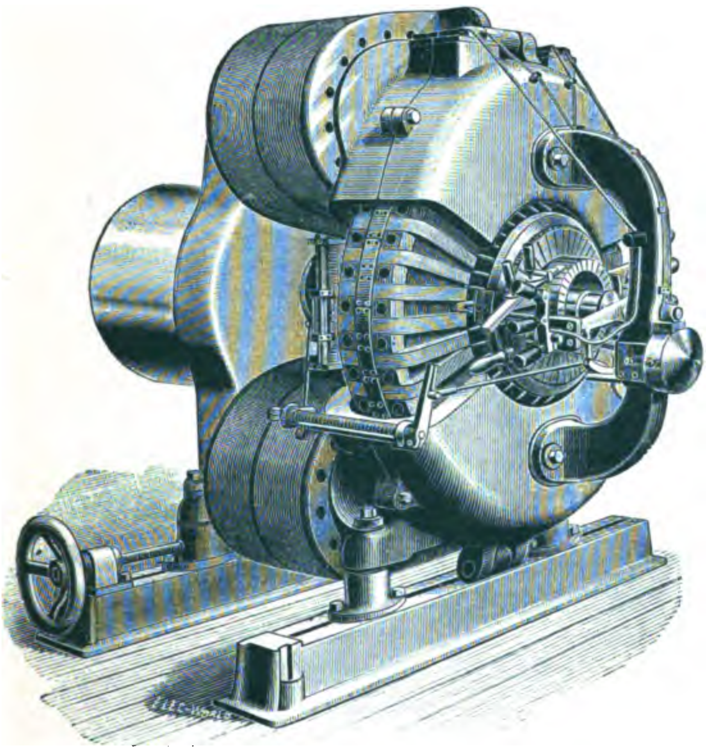


Fig. 111—"Excelsior" Belt-Driven Arc-Light Generator.

Fig. 113, taken in connection with the accompanying table of dimensions, gives the sizes in which these machines are constructed.

A 75-light continuous-current belt-driven arc-light generator, of the Westinghouse Electric and Manufacturing Company, is shown in Fig. 114. This machine has six poles, all connected in series. It is *separately excited;* i. e.. is supplied with a continuous current from a small separate continuous-current generator of about 1 K. W. capacity. The armature has two commutators C, C, placed side by side on the shaft beyond the bearing. The brushes are not shifted around this commutator by any automatic regulating mechanism. On the contrary, they remain in position during the operation of the machine, and the regulation is entirely effected by the magnetic effect of the armature upon the field magnets. If the current supplied by the machine becomes too strong, the armature becomes more powerfully magnetized, and thus, reacting on the field-magnets, weakens them so as to reduce the voltage generated by the machine to the point at which the normal current strength will be supplied. Even if the machine be short-circuited, the current strength will be very little in excess of its normal value. If, on the contrary, the current becomes too feeble, the mag-

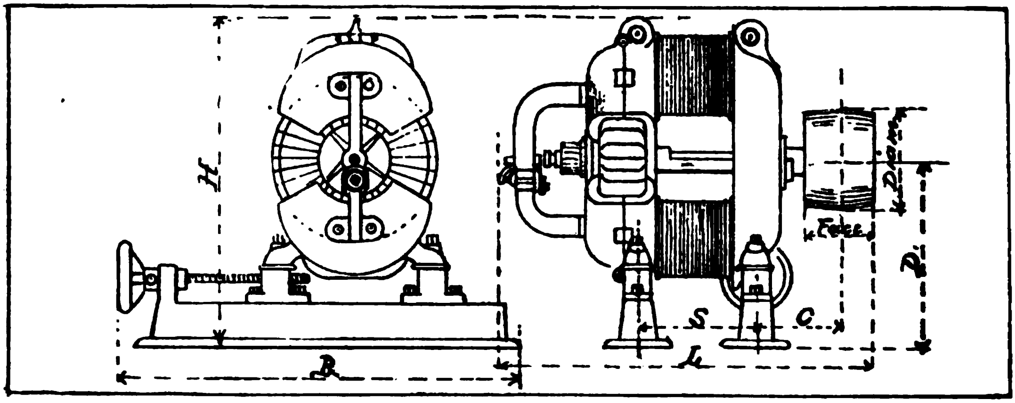


Fig. 113—Dimensions of "Excelsior" Constant-Current Arc-Light Generators.

TABLE OF DIMENSION OF EXCELSIOR ARC-LIGHT BELT-DRIVEN GENERATORS.

No. of Generator.	Kilowatt Capacity.	No. of Lights. 9.6 Amperes. 2,000 Nominal C. P.	No. of Lights. 6.8 Amperes. 1,200 Nominal C. P.	H. P. Required.	PULLEY.			Rev. per Minute.	H	B	L	S	C	D	Weight of Armature.	Weight of Dynamo Complete.	No. of Generator.
					Face.	Diameter.	Bore.										
A-6	70	——	200	104	16	30	3	650	68	68	82½	29½	16¾	37¼	1600	13500	A-6
A-7	75	150	——	115	16	30	3	650	68	68	82½	29½	16¾	37¼	1600	13500	A-7
A-8	43¾	——	125	65	12	20	2⅝	800	53	51¼	59¾	20½	12¼	28¼	740	6520	A-8
A-9	50	100	——	75	12	24	2⅝	800	53	51¼	59¾	20½	12¼	28¼	740	6520	A-9
A-10	35	——	100	52	12	20	2⅝	850	48¼	51¼	58⅞	18¾	13	26¼	680	5227	A-10
A-11	40	80	——	63	12	20	2⅝	750	53	51¼	59¾	20½	12¼	28¼	740	6520	A-11
A-12	26¼	——	75	40	10	18	$2\frac{1}{16}$	900	46	42½	53¾	17	11	25	458	3831	A-12
A-13	25	50	——	38	10	18	$2\frac{1}{16}$	900	46	42½	53¾	17	11	25	458	3831	A-13
A-14	15¾	——	45	24	8	14	$1\frac{11}{16}$	1100	38	37¾	43	15½	9¾	20½	260	2265	A-14
A-15	15	30	——	22	8	14	$1\frac{11}{16}$	1100	38	37¾	43	15½	9¾	20½	260	2265	A-15
A-16	7	——	20	11	6	10	$1\frac{9}{16}$	1200	32¼	37¾	39½	12½	6¾	18¼	148	1300	A-16
A-17	7½	15	——	12	6	10	$1\frac{9}{16}$	1200	32¼	37¾	39½	12½	6¾	18¼	148	1300	A-17

netic influence of the armature on the field-magnets becomes weakened, and the armature is enabled to develop an increased voltage. The armature, and the method of placing the coils in position upon it, are shown in Fig. 115. It will be seen that the armature has 8 poles, or polar projections, made up of sheet punchings, each of which has coils of wire *c*, *c*, slipped over it. *w*, *w*, are wedges holding the coils in place.

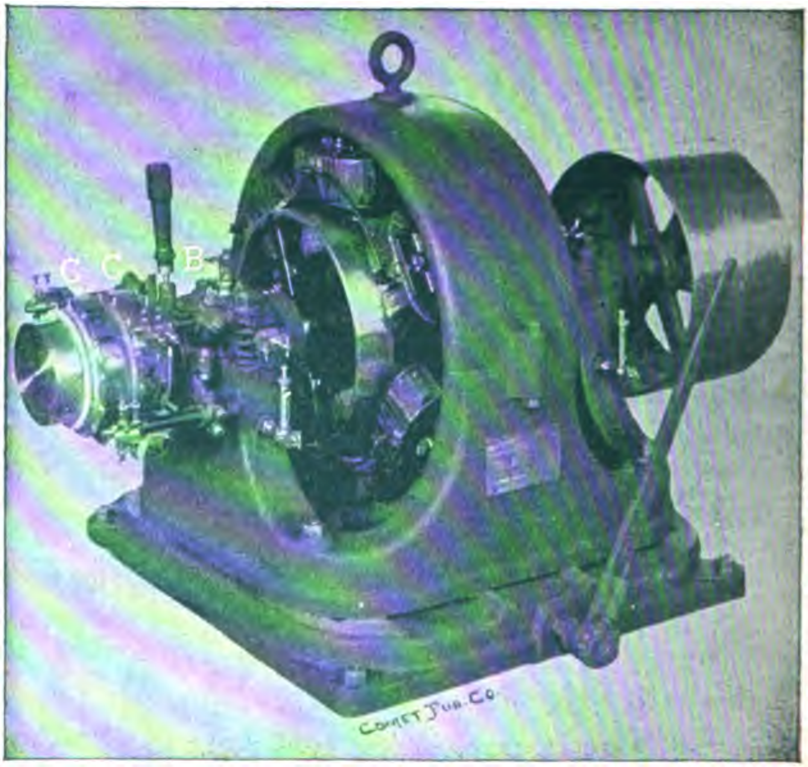


Fig. 114—Westinghouse 75-Light Direct-Current Arc-Light Generator.

Fig. 116, is a diagram of the armature connections of this machine. There are six poles, indicated by dotted lines n, s, n′, s′, n″, s″. The armature has 8 polar projections, 1, 2, 3, 4, 5, 6, 7 and 8, each carrying two coils in series, indicated by two turns on the drawing. The coils on opposite polar projections are connected in series between the opposite segments of one commutator. The two commutators are represented as concentrically surrounding the armature. Armature coil No. 1, is connected to segment No. 1′, coil No. 5, to segment No. 5′, and so on. Alternate polar projections have their coils connected to the commutators alternately. 1, 3, 5 and 7, to the external, and 2, 4, 6 and 8, to the internal commutator. The segments similarly numbered are in permanent electric connection. Thus, the three segments 1′, 1′, 1′, are all connected together. The pairs of brushes B and B′, are connected to the main terminals of the machine T, T′, while the other two pairs of brushes b and b′, connect the two commutators in series. The diagram represents the actual arrangement of connections, except that, for simplicity of representation, the inner commutator has been twisted through 60° in either direction. Thus the segments 2′ occupy in the diagram the positions corresponding to segments 6′ in the actual armature. Also, in the actual armature, the outside wires of each opposite pair of polar projections are connected together, and the inside wires are brought to commutator segments, in reverse to what is shown in the diagram.

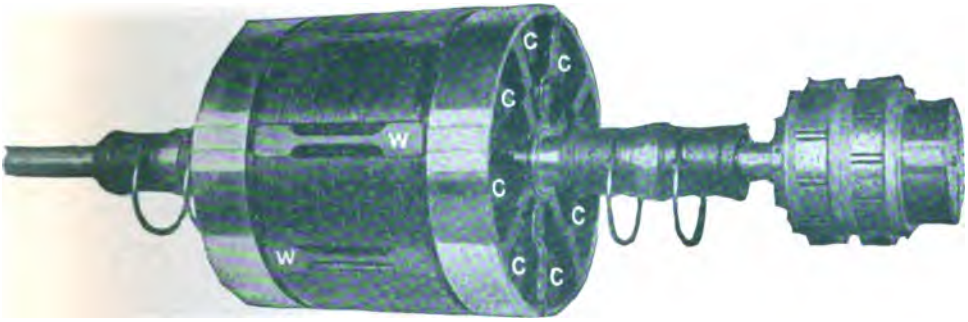


Fig. 115—Westinghouse Armature and Method of Placing Coils in Position.

It will be seen that the current divides in passing through the armature. Thus, commencing at brush B, the current divides through the paths 6′, 6, 2, 2′, and 8′, 8, 4, 4′, reaching

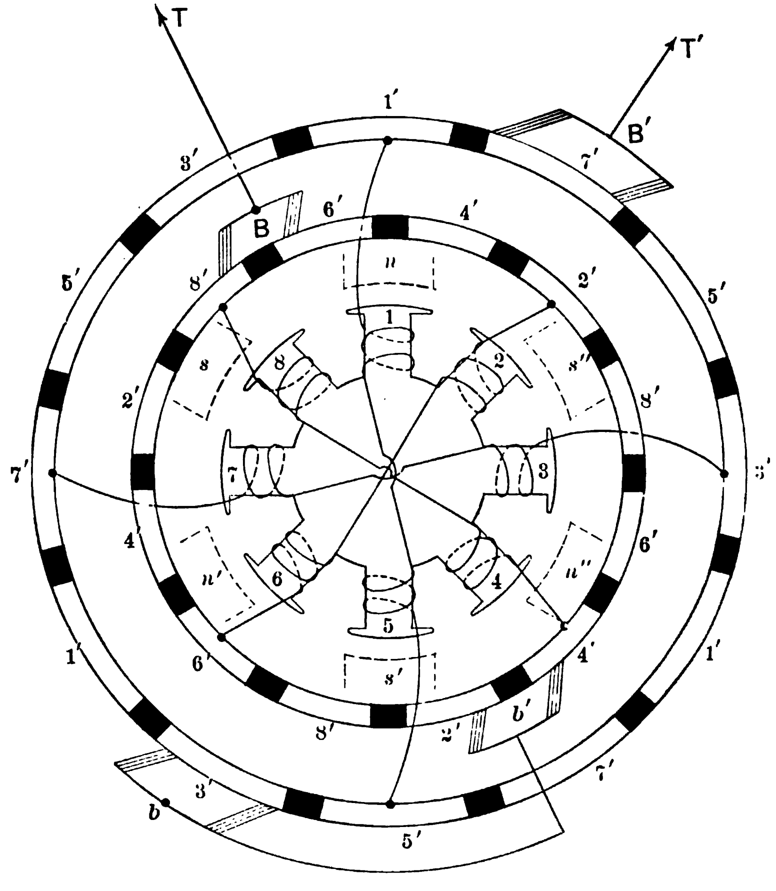


Fig. 116—Diagram of Westinghouse Arc-Light Generator Armature Connections.

the brush b′. It then flows in one stream to b 3′, 3, 7, 7′, and B′. The bifurcation occurs at each commutator alternately. Consequently, at any moment, there is always one pair of polar projections, such as 3 and 7, carrying the full armature current, and two other pairs, such as 2, 6 and 4, 8, which divide the full current between them.

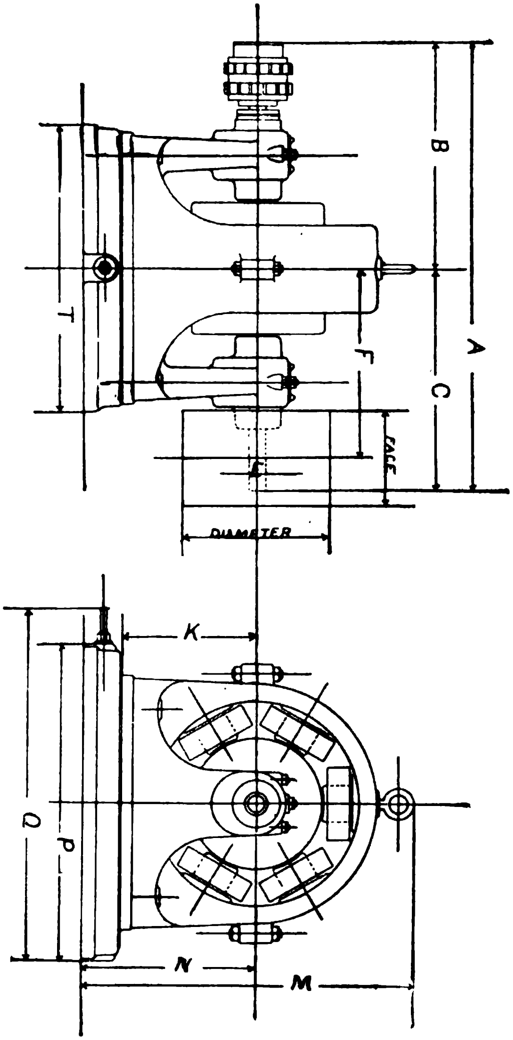


Fig. 117—Dimensions of Westinghouse Direct Current Arc-Light Generator.

Fig. 117, gives, in connection with the accompanying table, the dimensions of these machines

APPROXIMATE DIMENSIONS OF WESTINGHOUSE COMPANY'S DIRECT-CURRENT CONSTANT-CURRENT ARC-LIGHT DYNAMOS.

Lamps.	Volts.	Amps.	Revs.	Exciter.		A	B	C	E	F	K	M	N	P	Q	T	PULLEY.			Key-Way in Shaft.		Weight Net Lbs.
				Volts.	Amps.												Diam.	Face.	Length.	Width.	Depth.	
40	2000	9.5	900	125	6	58⅝	29⅝	29¼	2⅝	26⅛	16	40⅝	20	41⅛	45½	37⅛	19	10	6	⅝	¼	3000
50	2500	6.8	900	125	5	58⅝	29⅝	29¼	2⅝	26⅛	16	40⅝	20	41⅛	45½	37⅛	19	10	6	⅝	¼	3000
60	3000	9.5	825	125	7	63⅝	32¾	30⅝	2⅝	27	19½	46⅞	24⅞	45⅝	50¼	41⅛	21	14	7	⅝	¼	4100
75	3750	6.8	825	125	7	63⅝	32¾	30⅝	2⅝	27	19½	46⅞	24⅞	45⅝	50¼	41⅛	21	14	7	⅝	¼	4100
75	3750	9.5	650	125	8	71	35⅝	35⅝	2⅞	30⅝	21¼	52½	26¾	51¾	56¾	45¾	27	16	9	¾	¼	5900

The General Electric Company's Thomson-Houston type of belt-driven arc-light generator, is shown in Fig. 118. The field-magnet frame consists, as shown, of two cylinders of cast iron, provided with hemispherical pole-pieces embracing a spherical armature. This armature consists of three sets of coils of wire wound upon a ring so as to present a spherical outline. The three sets of armature coils are connected to a three-part commutator *C*, by the three wires which pass through the centre of the armature shaft and project beyond

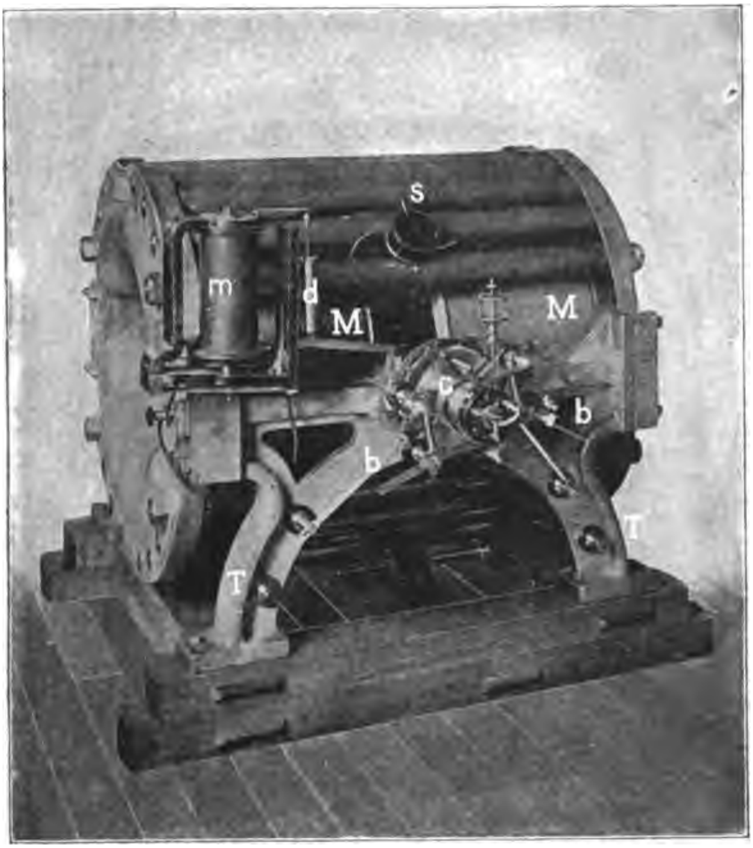


Fig. 118—"General Electric" Thomson-Houston Arc Dynamo.

it. Upon the commutator rest two pairs of brushes b, b. From these the current is led off, through the field-magnet coils M, M, and a regulator magnet coil m, to the external circuit. The strength of the current in the regulating magnet coil m, under the action of a "wall-controller," adjusts the position of the rocker arm holding the brushes, with reference

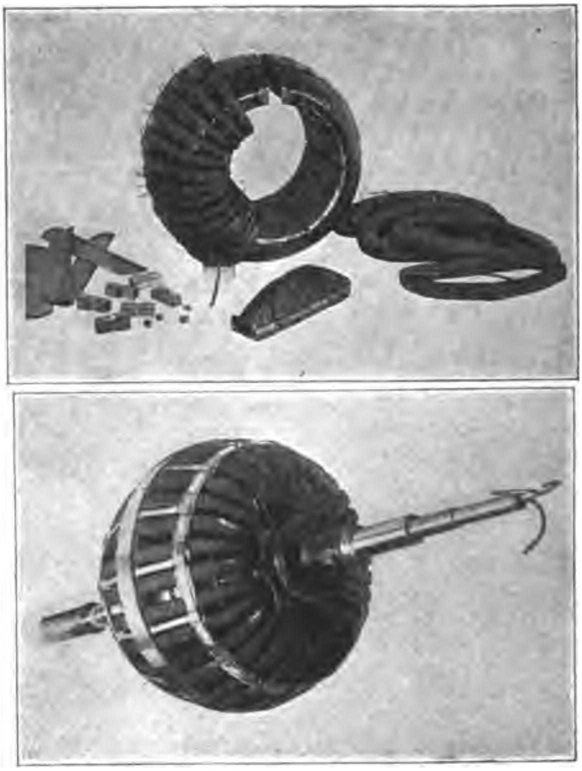


Fig. 119—"General Electric" T. H. Arc-Light Armature.

to the commutator C, thus varying the pressure supplied by the machine. The dash pot d, checks a too-rapid movement of the regulator magnet armature. T, T', are the main terminals. The switch s, is provided for short circuiting the field magnets when the machine is out of connection.

Fig. 119, shows the armature core and winding, and a completed armature of these machines. It will be seen that the coils are wound in a form and are then slipped into position on the core, being firmly maintained in position by wedges.

In order to place the coils on the core, a gap or slot is left in the core, and, after all the coils are in place, this gap is rigidly closed by a laminated wedge.

The connection between the armature coils is shown in Fig. 120. It will be seen that there are virtually three main coils on the core, each embracing a total segment of 120°. These are connected together to a common connection or copper ring, and their free ends are then brought to the three commutator segments as shown. There are never less than two of the three armature coils in circuit. The position of the brushes determines the effective pressure transmitted to the external circuit.

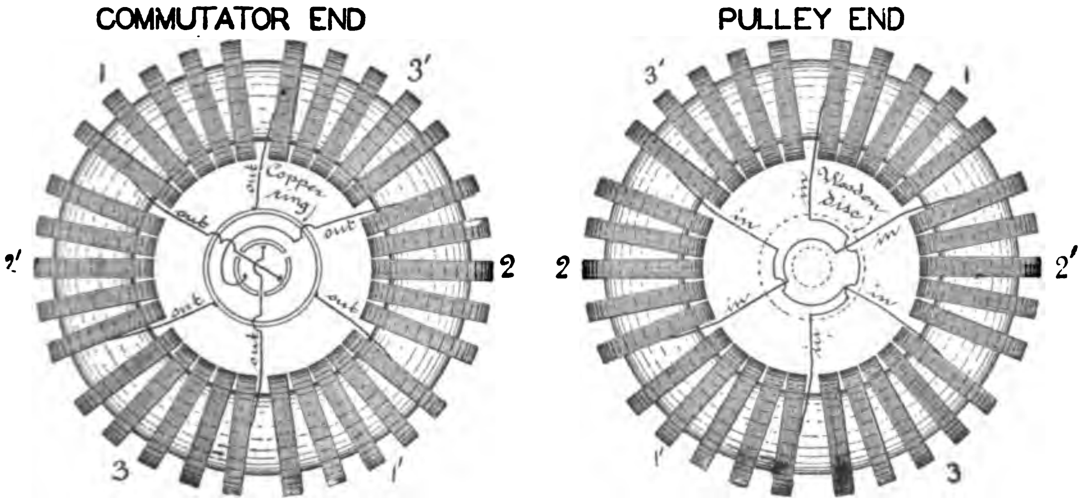


Fig. 120—Connections of Ring Armature for T. N. Arc Dynamos.

In order to prevent flashing around the commutator, a small air blast is employed, which removes the heated gases

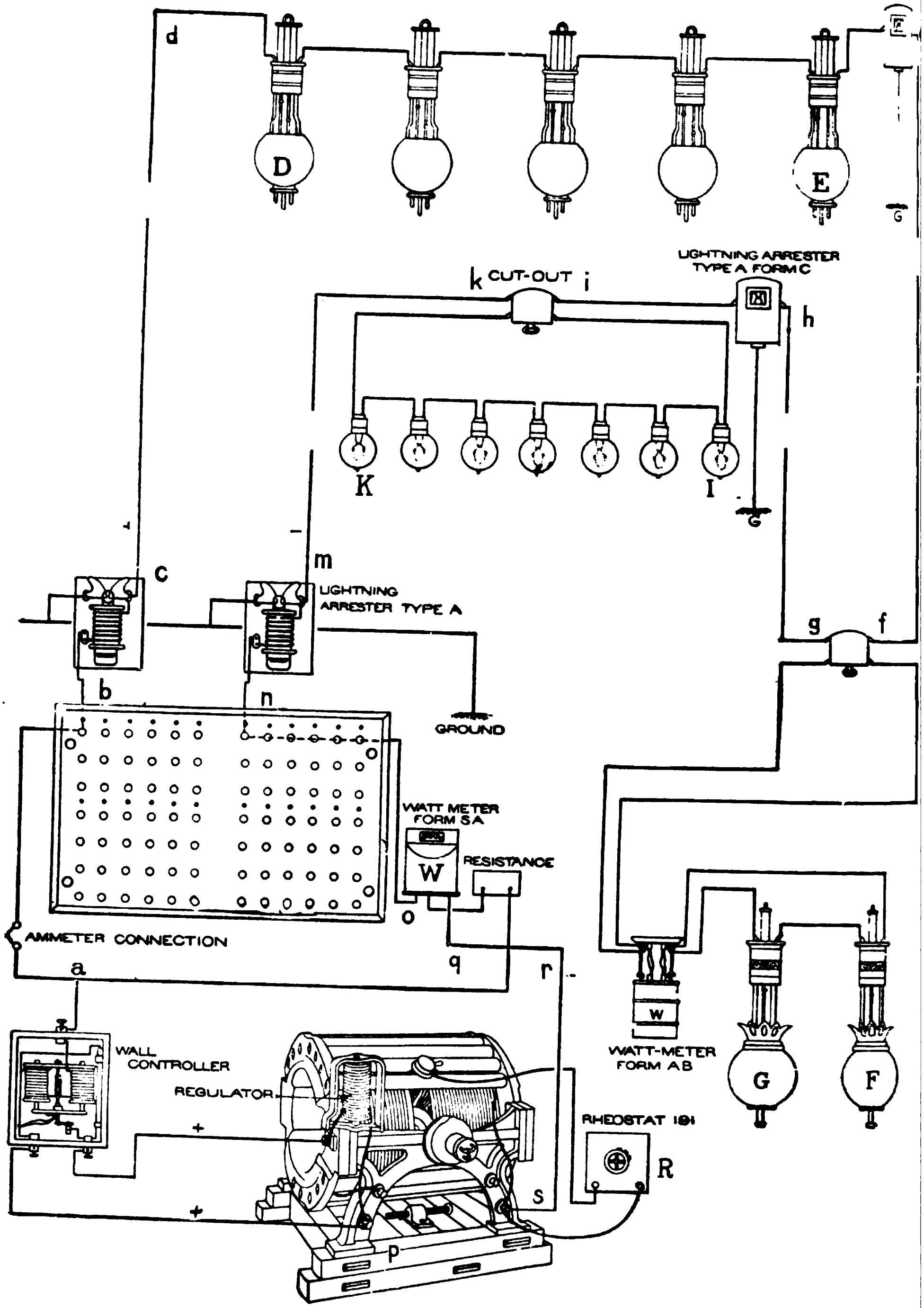


Fig. 121—Connections of "General Electric" Arc-Light Installation T. H. System.

and films of conducting matter which would otherwise be produced at the tips of the brushes when crossing the gap between adjoining segments on the commutator. The air blast acts so as to insert a continually renewed insulation in the slots between commutator segments.

The general connections are shown in Fig. 121. The current starts from *p*, the + terminal of the machine, and passes through the wall-controller to *a*, the switchboard *b*, lightning-arrester *c*, to *d*, the series arc-lamps *D* to *E*, lightning-arrester *e*, the cut-out *f g*, the lightning arrester *h*, the cut-out *i k*, the lightning arrester m, the switchboard at *n*, the wattmeter W, at *o q*, and by the wire *r*, to the negative terminal *s*. When the current is too weak, the wall-controller closes a contact short-circuiting the regulator, which moves the brushes to a position of more powerful pressure. When the current becomes too strong, the wall-controller lifts its armature and throws the regulator into the main circuit, thereby bringing back the brushes to a weaker position. The rheostat R,

THOMSON-HOUSTON ARC-LIGHTING GENERATORS.

Classification.	Kilowatt Capacity.	No. of 2000 C. P. Lamps.	No. of 1200 C.P. Lamps.	Weight.	Speed.	Approx. H. P. consumed.	PULLEY.			Floor Space. Length is parallel with Shaft.	
							Diam.	Face.	Bore.	Length	Width.
C	1.5	3	4	725	1250	3	8"	4½	1½"	33¾"	38½"
E	3	6	9	1450	1000	5	10"	5 "	1⅝"	43¾"	45½"
H	6	12	18	2200	950	10	12"	6 "	2⅜"	50¼"	50½"
K	10	20	30	3500	900	16	15"	8 "	2⅝"	60¾"	51½"
M	15	30	45	4200	850	23	15"	8 "	2⅝"	63½"	52¼"
LD	17.5	35	50	5200	820	27	16"	8 "	2⅞"	64 "	52¼"
MD	25	50	75	5975	820	38	18"	10 "	2⅞"	64½"	52¼"

is for short-circuiting part of the field-magnet coils, and thereby weakening the field, when it is desired to supply a small number of lamps in the circuit. When the handle of the cut-out i k, is pulled down, the series incandescent lamps I, K, are thrown into circuit. Similarly, when the handle of the cut-out f g, is pulled down, the arc lamps F, G, are thrown into circuit through the registering wattmeter w.

The accompanying table shows the dimensions of these machines.

A small arc switchboard with wall controllers and one ammeter is shown in Fig. 121 A. The insulating handles connected by insulated flexible cords make the required circuit connections between brass straps behind the board.

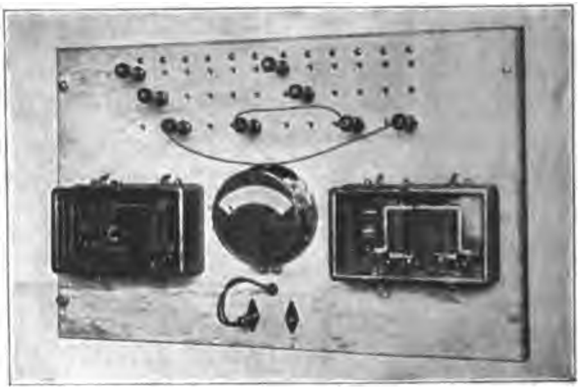


Fig. 121 A—Small Arc-Light Switchboard.

Fig. 122, shows a General Electric Company's Brush type of belt-driven arc-light generator, capable of supplying one hundred and twenty-five 2,000-candle-power arc-lights. This is a 60 K.W. machine, delivering 9.6 amperes at a maximum pressure of 6,250 volts, at 500 revolutions per minute. The armature is 39 inches in diameter and weighs 10,000 pounds, approximately. This machine, in a partially dismantled condition, for enabling the armature to be removed, is shown in Figs. 123 and 124. It will be seen that the upper halves of the field frames can be lifted off the machine. The armature, shown separately at Fig. 125, is of the Gramme-ring

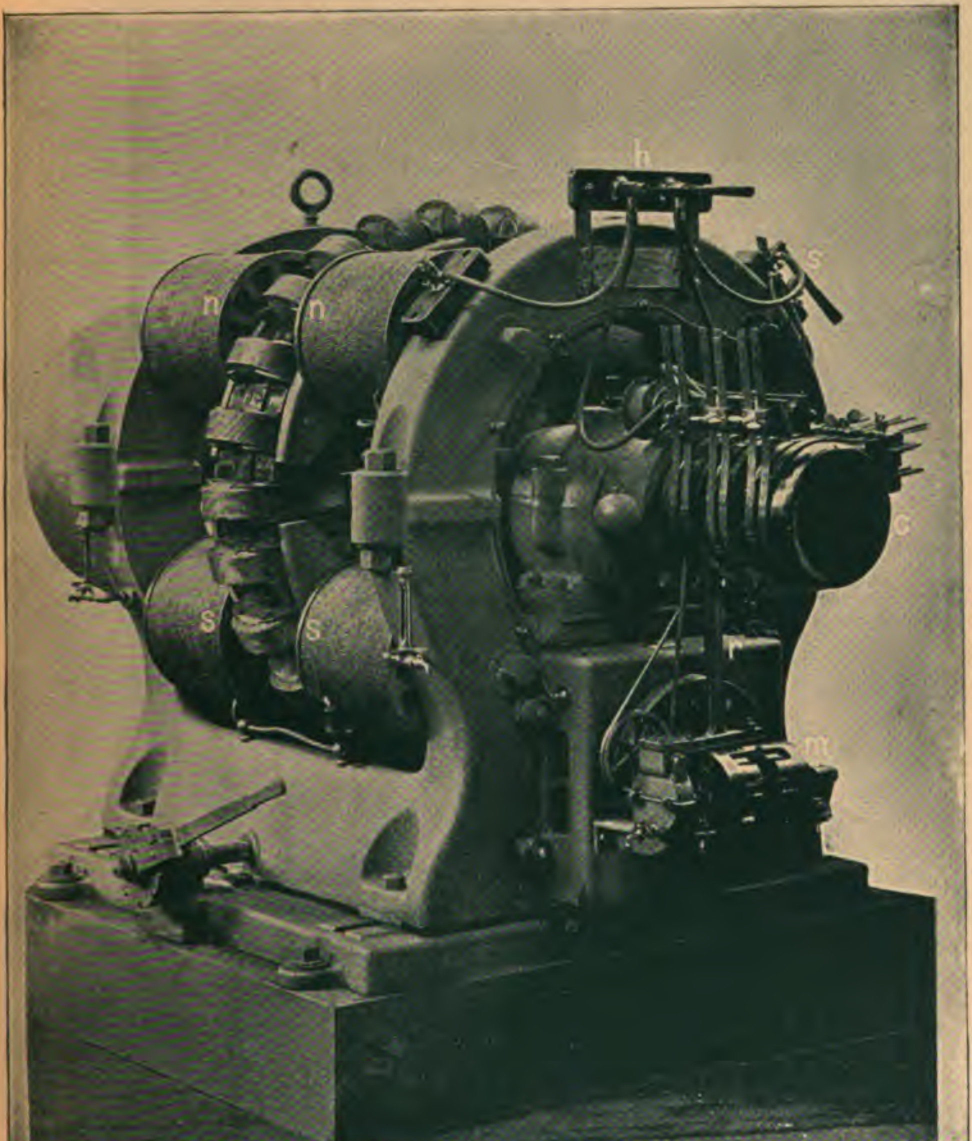


Fig. 122—125-Light 200 C.P. General Electric "Brush" Arc Dynamo with Regulator, Latest Design, 1896.

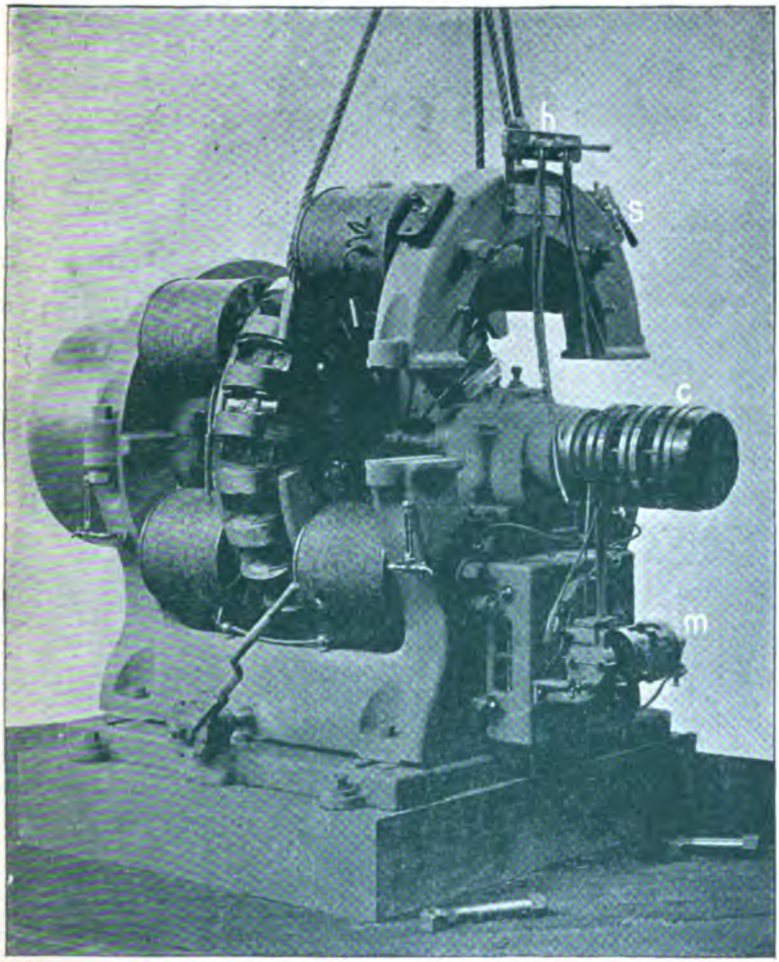


Fig. 123—General Electric "Brush" Arc-Light Generator with One Upper Field Being Removed.

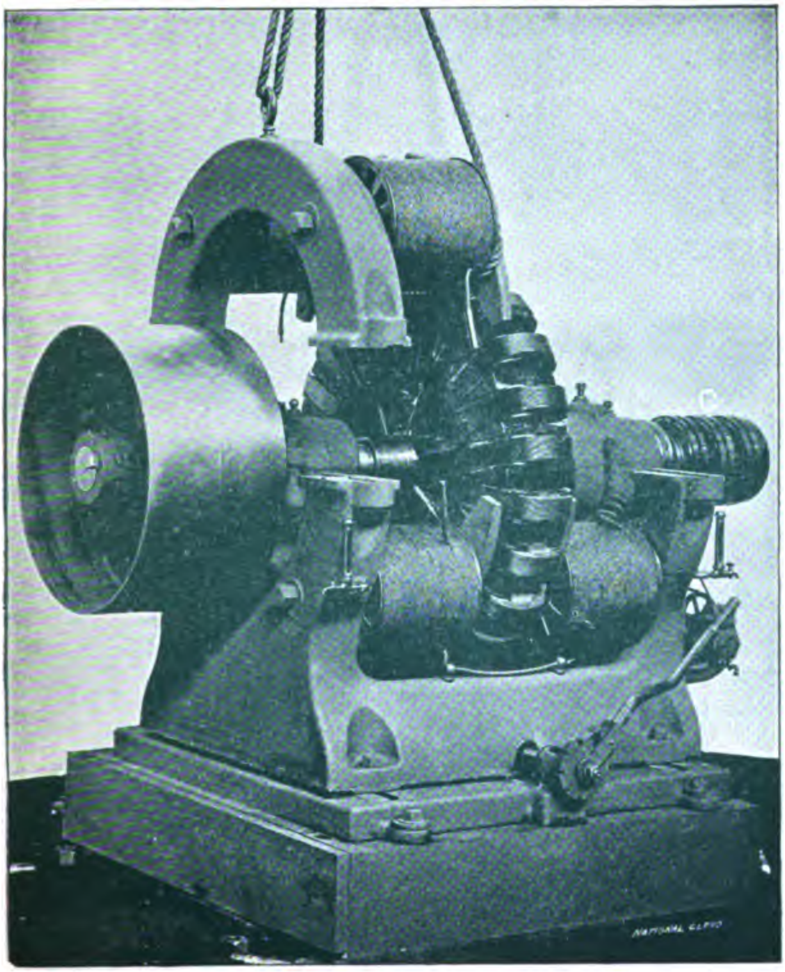


Fig. 124—125-Light 2000 C. P. General Electric "Brush" Arc Dynamo, Partially Disassembled.

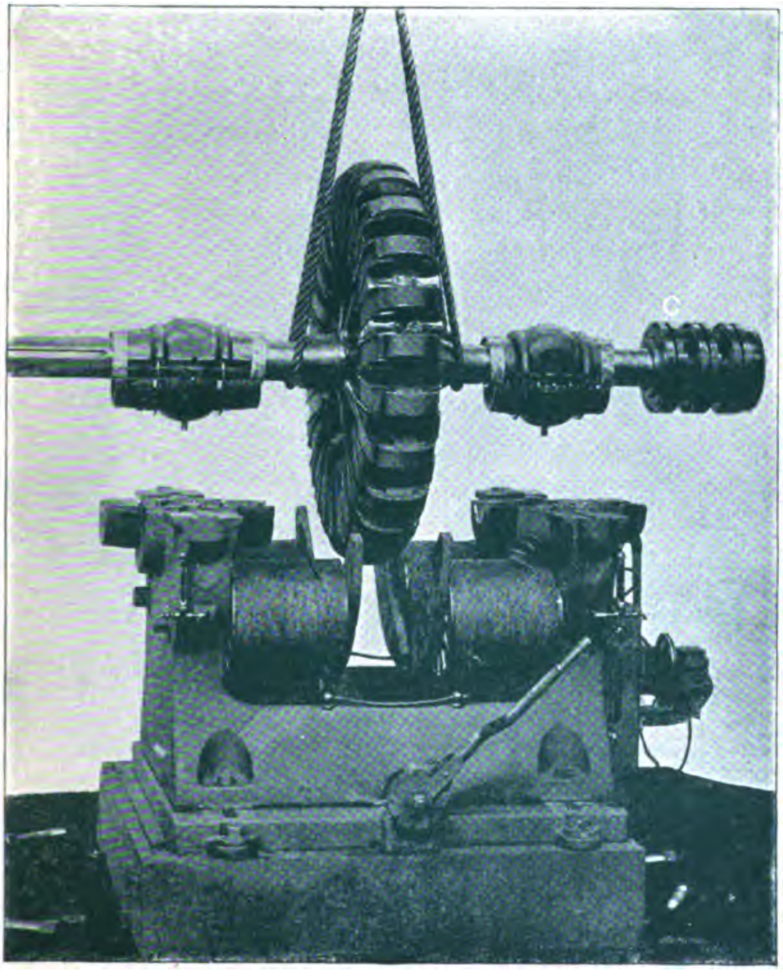


Fig. 125—Armature of 125-Light 2000 C. P. General Electric "Brush" Arc Dynamo.

type, the coils being wound in slots, so as to leave polar projections between them on each face of the armature. There are 8-magnet coils, four on each side of the machine, and opposite coils produce poles of the same name as indicated in Fig. 122. The commutator C, is made up of three separate commutators, placed side by side. Three sets of brushes which rest upon them, are connected in series with the field-magnet coils and the external circuit. The armature connections are shown in Figs. 126 and 127. Fig. 126, shows four segments connected in series and brought to one com-

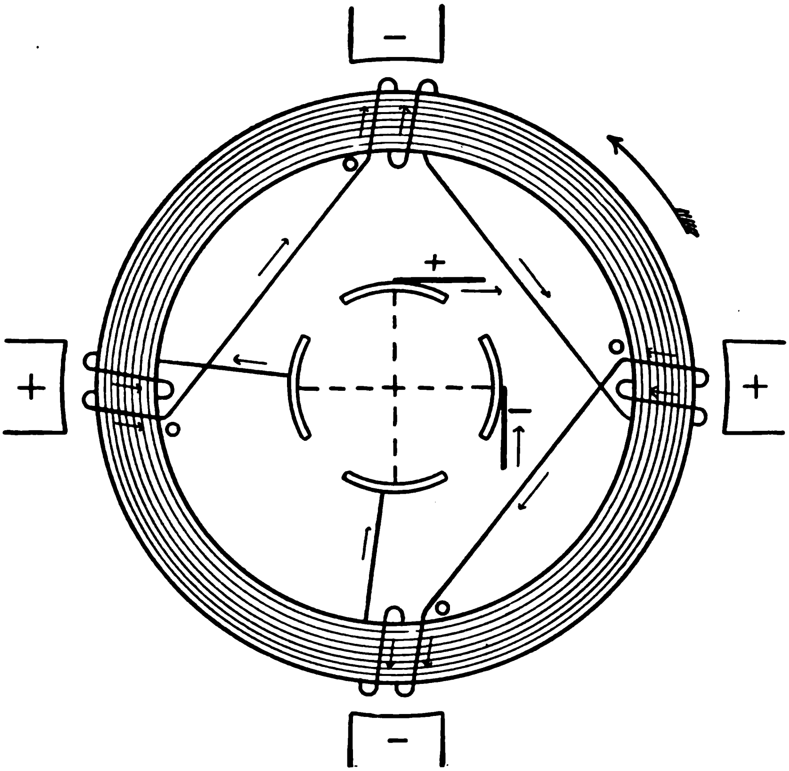


Fig. 126—Diagram General Electric "Brush" Type of Arc-Light Generator.

mutator. As each commutator is double, there are eight segments connected therewith, as shown in Fig. 127. Each of the three commutators being similarly connected with its own armature segments, there are 24 armature coils and 12 wires

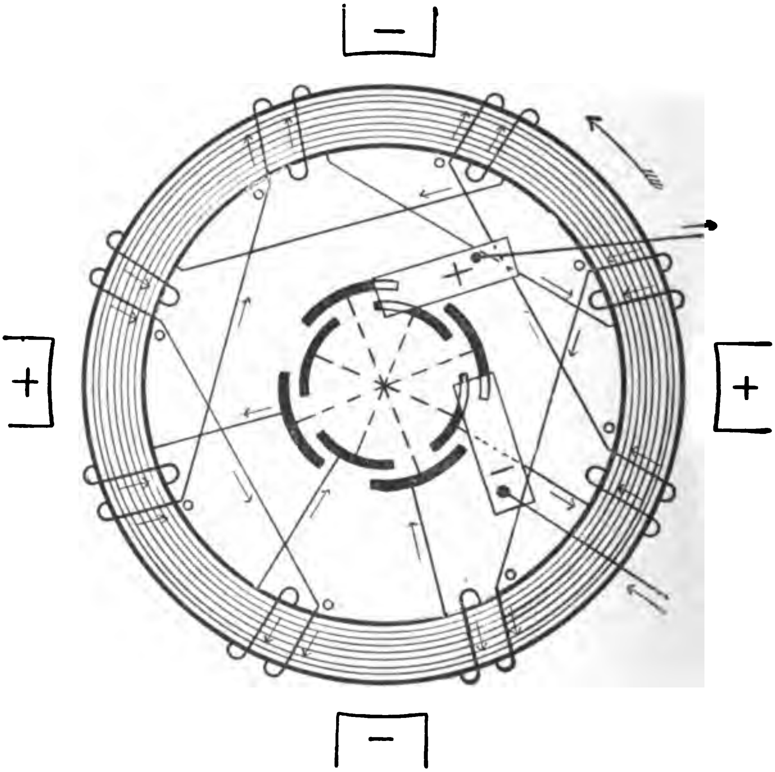


Fig. 127—Diagram showing Parallel Connections between Commutator and Armature.

between armature and commutators. S, is a switch for short-circuiting the field magnets ; h, is a switch for short-circuiting the armature. The regulating device of this machine consists of the pair of electro-magnets m, which are mechanically rotated in opposite directions about a common axis. Between

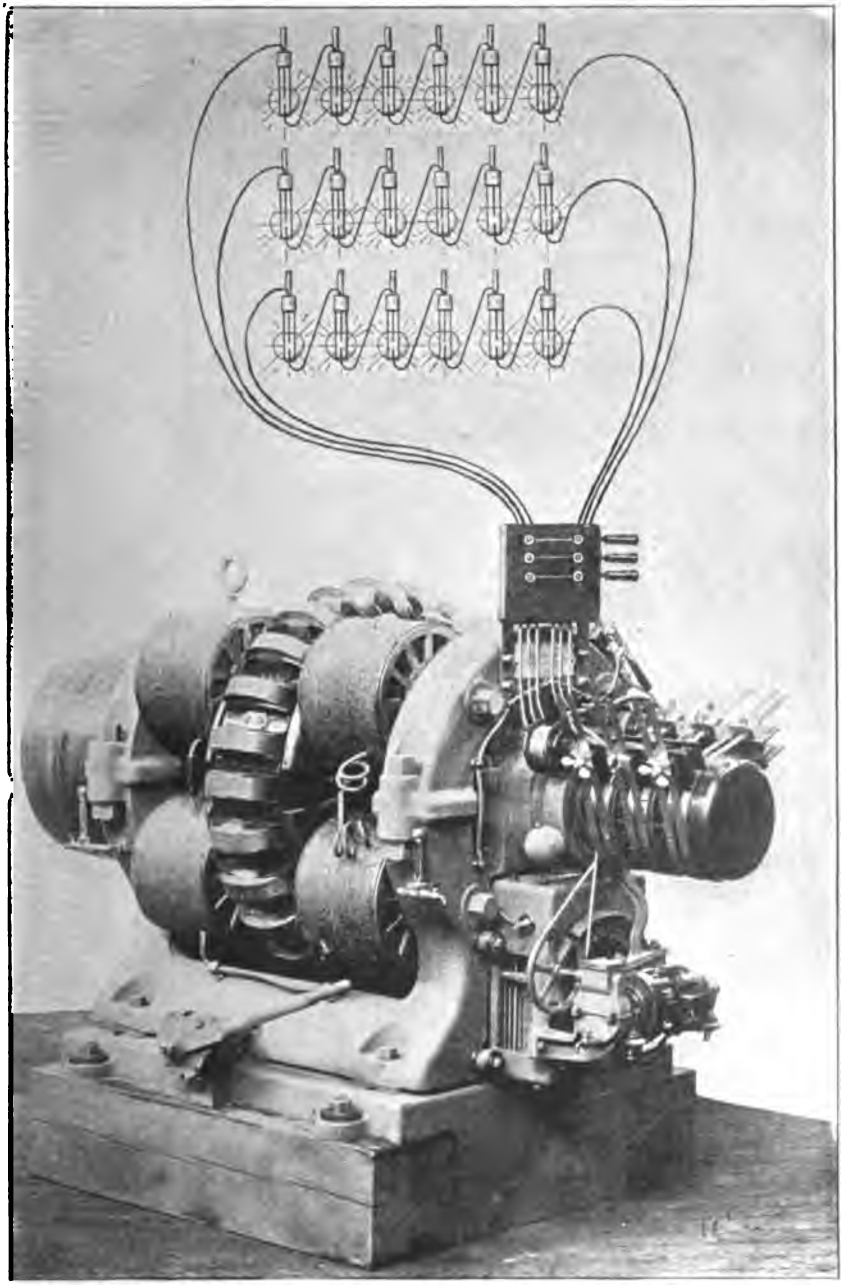


Fig. 128—General Electric "Brush" Multi-Circuit Dynamo.

them lies an armature, so arranged that it can be clutched by whichever of the two revolving magnets happens to be excited. The armature, when so clutched, causes a contact arm to be revolved over the face of a shunt field-rheostat r, by which the current strength circulating in the field-magnet coils is automatically adjusted. The clutch magnets are excited by a separate electro-magnet placed in the main line circuit, which is adjusted to close one circuit or the other, according as the current strength in the line is too great or too feeble.

Fig. 128, is a General Electric Company's Brush multi-circuit arc-light generator. This machine is capable of supplying, as shown, three separate series circuits from the same armature. By this means the E. M. F. of the machine for a given type is reduced practically to one-third of what it would be if all the lamps had to be operated in a single circuit. Each of the switches s, s, s, controls one of the three circuits. The switch S, serves to short-circuit the field coils when the machine is out of action.

The accompanying table shows the dimensions of these machines:

TABLE OF BRUSH ARC-LIGHTING GENERATORS.

Classification.	Kilowatt Capacity.	No. of 2000 C. P. Lamps.	Weight.	Speed.	Approx. H. P. consumed.	PULLEY.			FLOOR SPACE.	
						Diam.	Face.	Bore.	Length	Width.
No. 8	31	65	5375	950	47	20"	12½"	2¾"	88⅝"	32¼"
No. 9	38.5	80	6300	700	59	22"	12½"	3¾"	75¼"	46⅞"
No. 10	48	100	7250	600	73	26"	12½"	3⅞"	78 "	49¼"
No. 11	60	125	9590	500	91	28"	12½"	4⅝"	84½"	55¾"

Should any armature coil become damaged, it may be readily cut out, without throwing the machine out of use.

CHAPTER VI.

SOME MISCELLANEOUS TYPES OF CONTINUOUS-CURRENT GENERATORS.

CONTINUOUS-CURRENT generators are frequently employed for producing the electric current needed for ***electrolytic decomposition***, such, for example, as the deposition of silver on silver-plated articles, and of copper, in depositing vats. A type of small *electrolytic machine*, with a comparatively powerful current at two or three volts pressure, is represented in Fig. 129. Since the E. M. F. required for producing elec-

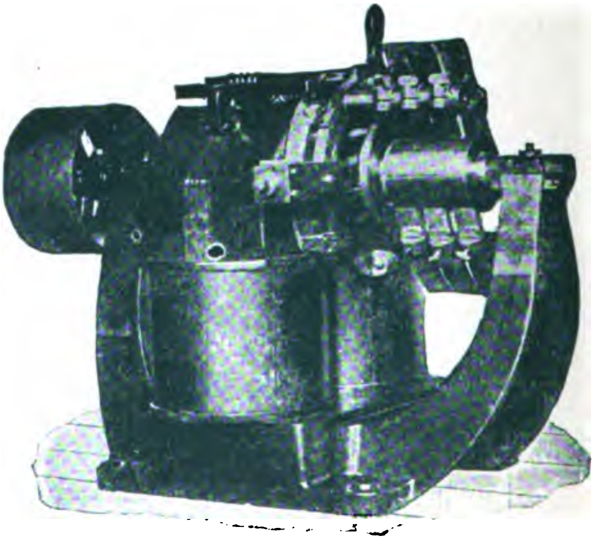


Fig. 129—Excelsior Electric Electrolytic Generator.

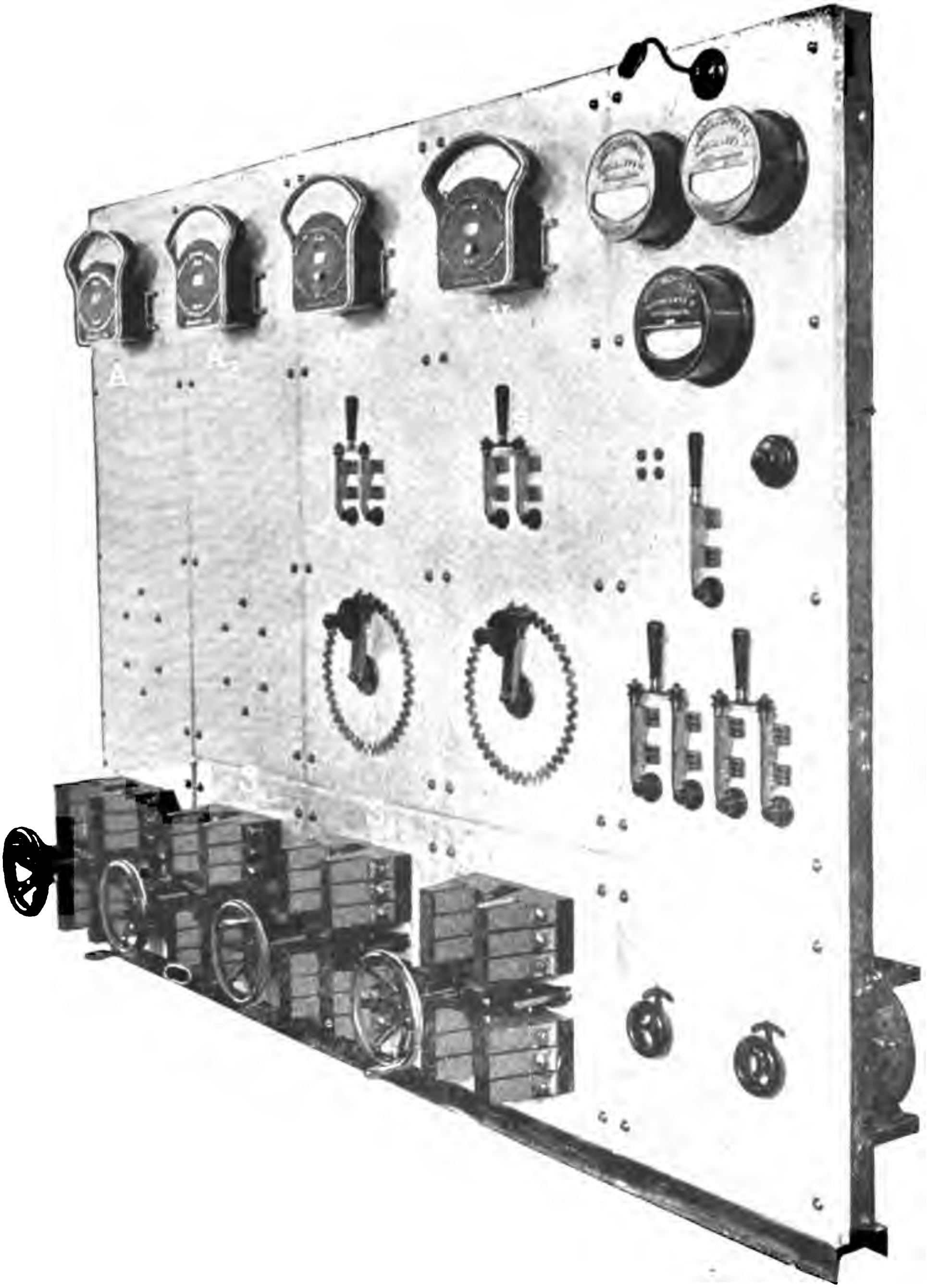


Fig. 131—"Westinghouse" Switchboard for Two 810 K. W. Electrolytic Generators.

trolytic decomposition in a single tank or bath is quite small, usually between one-third of a volt and five volts, the armature of a machine, suitable for connection to a single tank, has very few turns of wire; but, since the number of amperes required is often large, the armature turns must have in such cases correspondingly large cross section. The brushes and commutator must also necessarily be proportioned to the current delivered.

In the electrolytic refining of metals a number of tanks are usually connected in series, so that the E. M. F. of the electrolytic generator has to be correspondingly increased. Fig. 130, shows a pair of Westinghouse Electric and Manufacturing Company's electrolytic, 810 K. W. generators, for delivering, at a speed of 130 revolutions per minute, 4,500 amperes each, at a pressure of 180 volts. These machines are of the engine

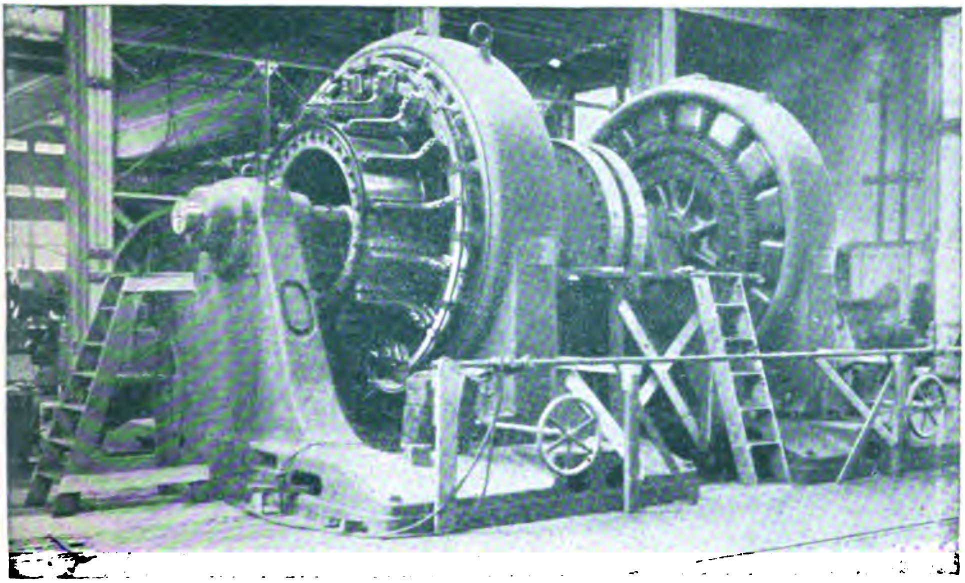


Fig. 130—Pair of "Westinghouse" Electrolytic 810 K. W. Generators.

type already described in chapter III, the field frames being capable of vertical separation into two halves. The machines have 16 poles, and 16 sets of carbon brushes, each set containing 8 brushes. The machines are shunt-wound, and are capable of being separately or self-excited. They are shown as coupled together in the figure,but are intended for direct connection through belt-coupling with a turbine, and are installed at the works of the Boston and Montana Consolidated Copper and Silver Mining Company at Great Falls, Montana. They are ring-connected machines of the type represented in Fig. 15. They have, at full load, an efficiency of 95%, and are capable of running at full load for an indefinite period at a maximum temperature elevation of 40° C. When self-excited, these machines are capable of withstanding a short-circuit without injury, because, should such a short circuit occur, the powerful currents thereby excited in the armature react upon the magnetism of the field and neutralize it.

The switchboard for these machines is shown in Fig. 131. A_1, A_2, are the ammeters, each reading up to 6,000 amperes. V_1, V_2, the voltmeters. R_1, R_2, the field rheostats, the circuits of which are closed through the switches s_1, s_2. S_1, S_2, S_3, S_4, are the main switches, each consisting of a pair of heavy copper bars, of 6 square inches cross-section, pressed forward by screws, operated by hand-wheels, into the grip of copper-strip jaws. S_1 and S_3 are the positive and negative switches for one generator, and S_2, S_4, for the other generator. The currents are supplied to a common pair of bus-bars. The panel on the right-hand side is for two separate exciters, which may be run singly or in parallel, w_1, w_2, being their switches, r_1, r_2, their shunt rheostats, a_1, a_2, their ammeters, and v, their voltmeter.

Special arangements are made in order to prevent these machines from being suddenly open-circuited under load, thus endangering the driving turbine, before its governor could close the gate. Should an open circuit occur, the machines are short-circuited upon on artificial load in the power-house.

Fig. 132, shows the main conductors which carry the current from these generators to the electrolytic refinery, a distance of 2,200 feet. These conductors are copper bars of 24 square inches cross-section, cast in 20-feet lengths and soldered together at their extremities. They are insulated on glass blocks and supported on trestles. The loops shown are expansion joints.

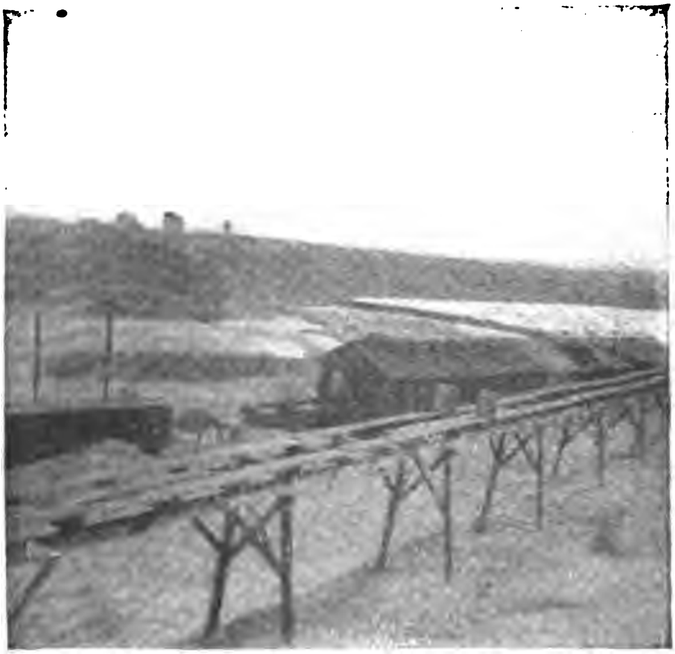


Fig. 132—Main Conductors for Westinghouse Electrolytic Generators.

Fig. 133, shows a Westinghouse Electric and Manufac-Company's switchboard for four 270 K. W. 3,600-amperes, 75-volt electrolytic generators, or for 1080 K. W. in all, and intended to supply any one of four circuits from any one of four generators. Each pair of panels A, B, is for one generator; A, being for positive terminals, and B, for negative terminals. M, M, are generator ammeters; v, v, voltmeters;

F, F, field rheostats; and S, S, main generator switches. These consist of massive copper bars which are forced into copper jaws by the hand-wheels shown.

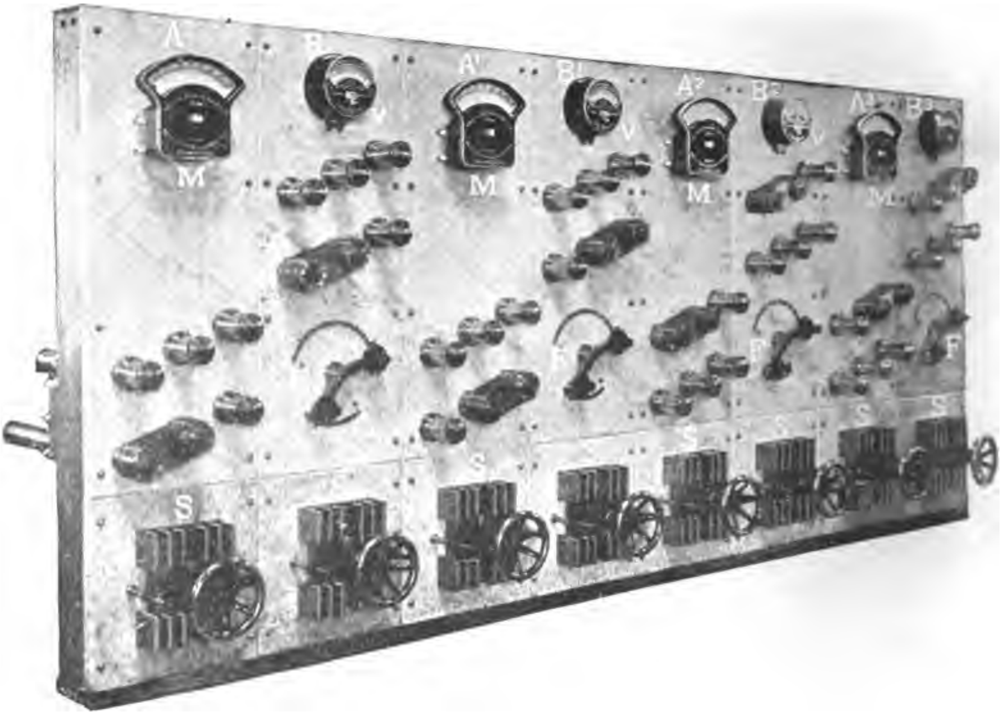


Fig. 133.—Westinghouse Switchboard.

The back of this switchboard is shown in Fig. 134. U, U, U, U, form jointly the upper or negative bus-bars, and L, L, L, L, the lower or positive. P, P, P, P, are the main switch lugs for the reception of the positive cables from the generators, and N, N, N, N, for the negative cables.

Fig. 132, shows a Crocker-Wheeler Electric Company's small belt-driven generator for telegraphic purposes. In telegraphy, a current of from $\frac{1}{30}$ to $\frac{1}{40}$ ampere is usually re-

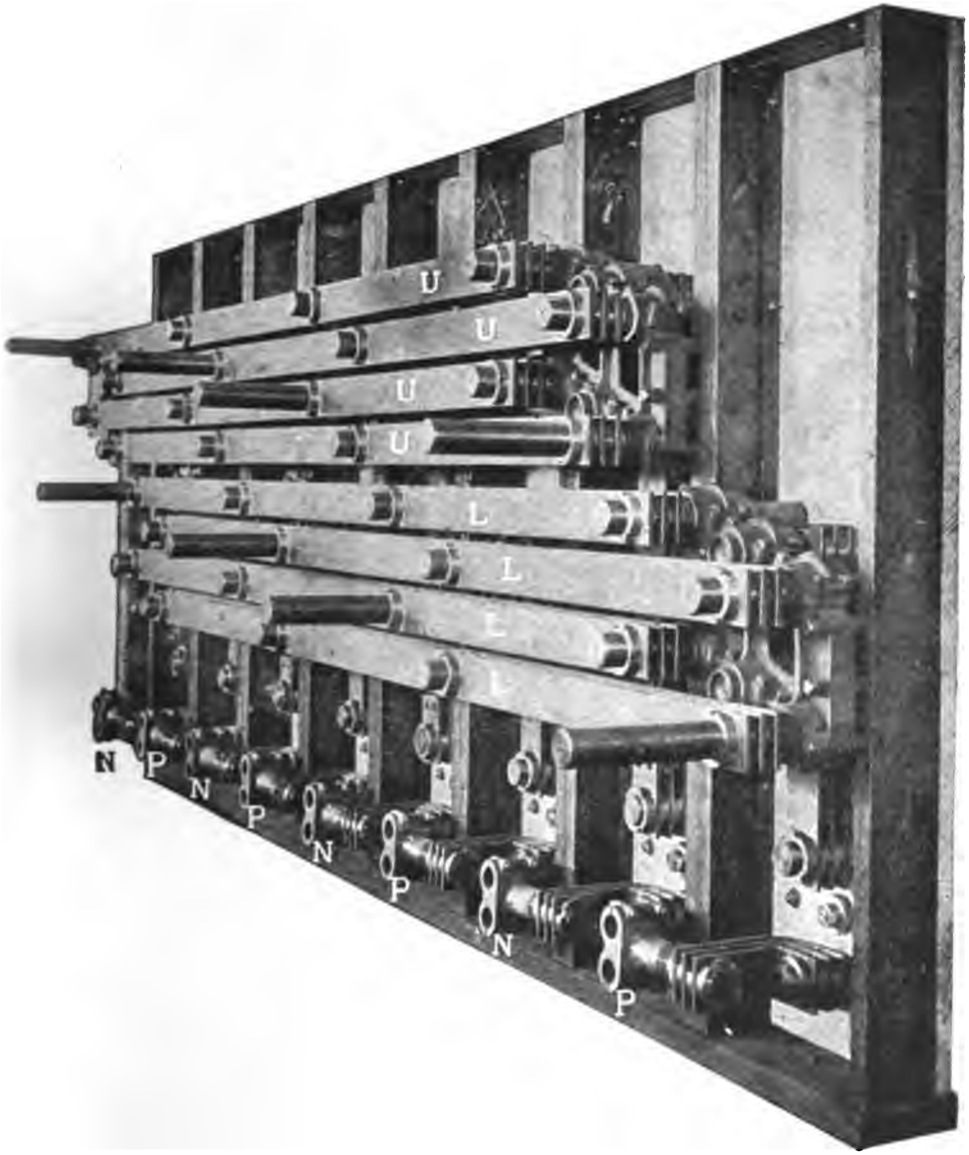


Fig. 134—Rear View of Switchboard in Fig. 133.

quired to operate each Morse circuit. A small shunt-wound dynamo of suitably low resistance is capable of supplying a number of such circuits. The dynamo shown is of 110 watts capacity, and such a machine is usually wound for about 70 volts pressure.

Fig. 136, shows a multipolar Thompson-Ryan belt-driven 25 K. W. generator. This machine differs from those heretofore described in the fact that its field frame is provided with an additional winding in circuit with the armature and called a balancing winding. Its function is to balance or compensate the magnetizing influence which the armature current exerts on the field. In the ordinary dynamo, the distribution of magnetic flux, which is generated by the field magnets, is distorted to a greater or less extent by the magnetic influence of the current passing through the armature. In other words dynamos possess an *armature-reaction* which increases with the

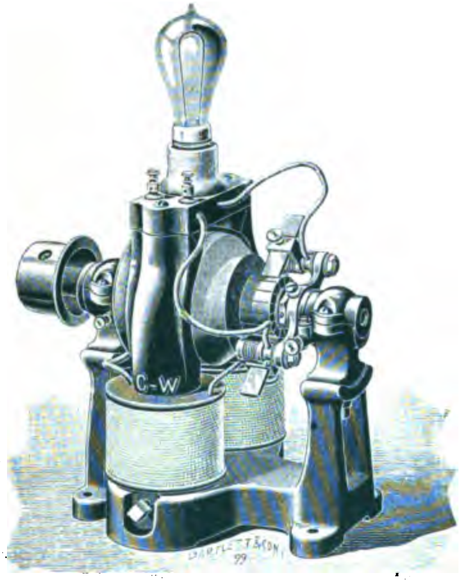


Fig. 135—Crocker-Wheeler Telegraph Dynamo.

load. The armature-reaction may be sufficiently marked to limit the current delivered by the armature, as in the case of arc-light machines, such, for example as that shown in Fig. 114. This reaction tends to reduce the output of the machine, and moreover increases the sparking. The forward lead which has to be given to the brushes of an ordinary generator under load, in order to produce sparkless commutation, is partly due to armature reaction. In the Thompson-Ryan dynamo, the reaction is prevented by oppositely magnetizing the armature under load through the action of the balancing coils. The manner in which this is effected will be evident from an inspection of Fig. 137. Here the field frame is wound with the ordinary field windings a, a,

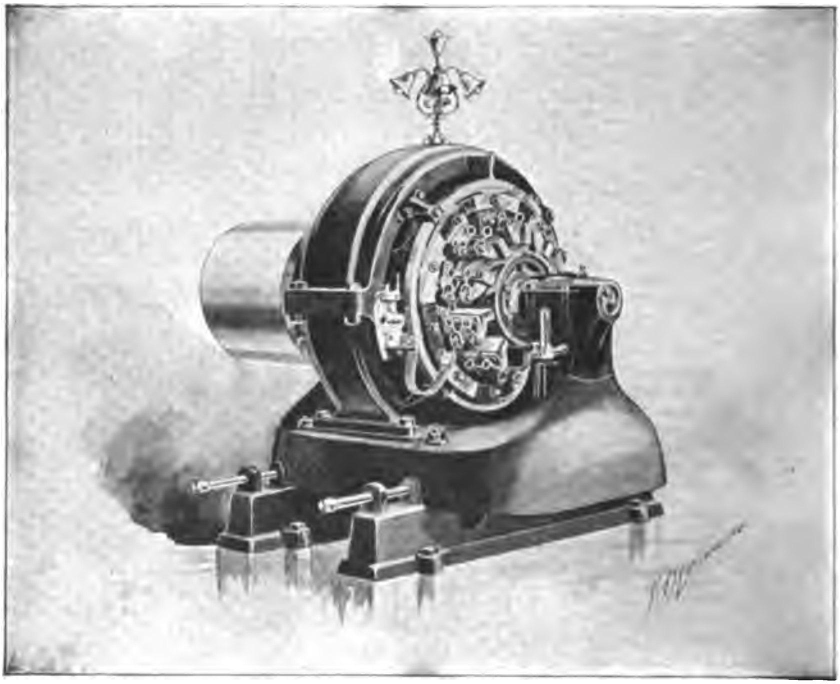


Fig. 136—Thompson-Ryan Belt-Driven Generator.

b, b; and in addition, the balancing coils are wound in the grooves m, n, k, l, o, p.

If no current flows through the armature, the coils a, a, b, b, only, are active. The balancing coils, like the series coils of an ordinary compound-wound machine, are connected in series with the armature. As shown in Fig. 137, the armature is iron-clad with deep grooves. When current flows through the armature, the magnetic reaction produced by the armature coils is cancelled by the opposite magnetic effect of the balancing coils. Fig. 138, shows the field ring of a

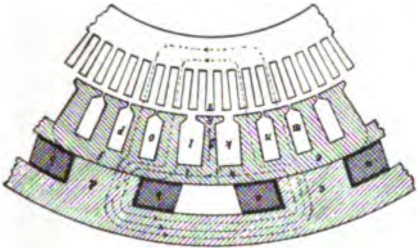


Fig. 137—Section of Thompson-Ryan Armature.

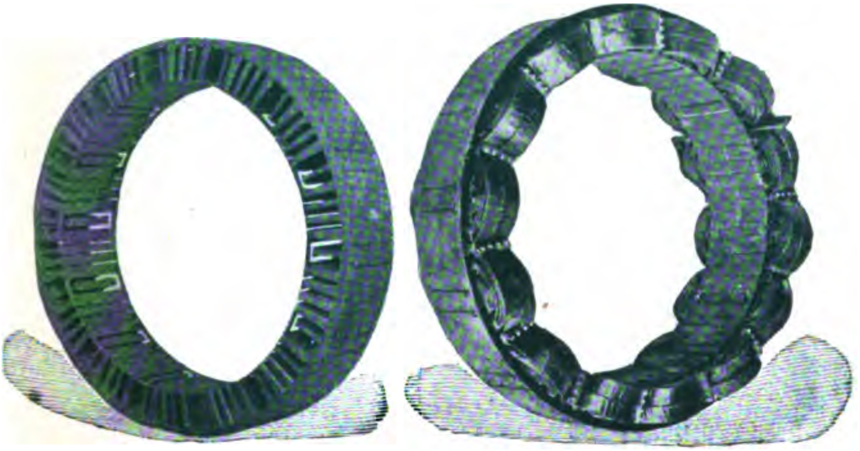


Fig. 138—Unwound and Wound Field Ring of Thompson-Ryan Generator showing Balancing Coils.

200 K. W. Thompson-Ryan generator of 14 poles. This ring slips into the field frame within the true field windings. It is claimed for these machines that although they require the balancing winding in addition to field and armature windings, yet they yield a large output, 15 to 20 watts per pound of total weight being claimed for slow-speed direct-connected generators.

A Ridgway Dynamo & Engine Company's 10-pole Ryan generator is shown in Fig. 139 directly connected to one of their engines.

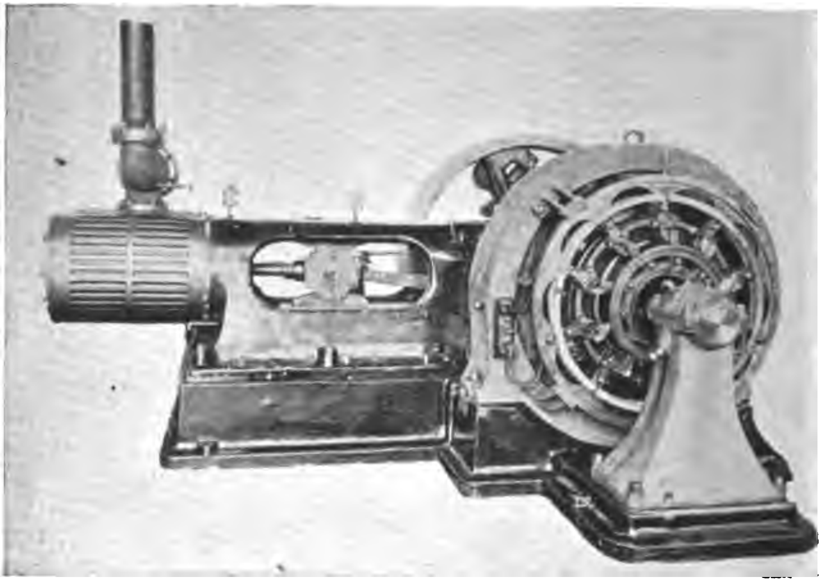


Fig. 139—Ridgway Dynamo & Engine Company's Multipolar **Direct-Driven** Generator.

CHAPTER VII.

ALTERNATING-CURRENT GENERATORS.

THE generators we have hitherto considered have all been of the direct-current, or continuous-current type; that is, the current always flows in the same direction through the circuit connected with them. We will now consider types of generators in which the current *alternates;* i. e., flows first in one direction, and then in the opposite direction, alternately in rapid succession.

Alternating-current generators can be divided into two sharply-marked classes; namely, *single-phase* or *uniphase*, and *multiphase* or *polyphase generators.* We shall in this chapter confine our attention to single-phase or uniphase machines; or, as they are sometimes called, *uniphasers.*

A uniphaser is a machine which supplies at its terminals a single alternating current for use in its external circuit. Such machines are now employed almost exclusively for alternating-current incandescent lighting. They are occasionally used for arc lighting, and, in rare instances, for the transmission of power, and for electric furnaces.

In the United States, uniphasers were formerly constructed which reversed the current in their circuits about 16,000 times per minute; that is to say, the *frequency* of alternation they supplied was 16,000 alternations per minute; or, about 266 alternations per second, representing a frequency of what is called 133 cycles per second, a *cycle* being a double-alternation, or a complete to-and-fro electric impulse. At the present time, the frequency of most uniphasers that are now constructed is much lower; namely, about 7,200 alternations per minute; or 60 cycles per second. The reasons for employing the higher frequency at the earlier period were found in the economy of material which was thus obtained in the *transformers*, or devices for reducing the pressure at subscribers' premises. Although uniphasers are still constructed, having a frequency either of 133 or 125 cycles per second, according to the particular system adopted, yet the lower frequency of 60 cycles per second is rapidly coming into favor.

Since each coil in the armature of a uniphaser must pass as many magnet poles in a second as it supplies alternations in that time, it is evident that a 60-cycle uniphase armature coil has to pass 120 magnet poles per second, while a 133-cycle uniphase armature coil has to pass 266 magnet poles per second. Consequently, a *high-frequency alternator* requires either to be run at a higher speed, or to have a greater number of magnet poles in the field magnets around the armature. The advantages of the 60-cycle frequency are:

First, that the speed of running can be conveniently reduced.

Second, that arc lamps can be more readily operated by alternating currents at the lower frequency.

Third, that the regulation of pressure in the alternating-current system supplied is improved; and

Fourth, that small motors, such as fan motors, are more readily operated from the circuit.

The fact that the transformers have to be somewhat increased in size, with a reduced frequency, has been largely offset by improvements which, of recent years, have been introduced in the manufacture of transformers.

Fig. 140, shows the Westinghouse Electric Company's form of 60 K. W. single-phase alternator or uniphaser. This is a belt-driven machine, with 8 poles, driven at a speed of 900 revolutions per minute, and, therefore, having a frequency of 8 × 900 = 7,200 alternations per minute, or 60 cycles per second. It is provided with two collector rings r, r, at the extremity of its armature shaft. Brushes b, resting upon these rings, serve to deliver the current to the external circuit. The pressure for which this machine is wound is usually either 1,100 or 2,200 volts. The two wires, which are required for the distribution of the current, are connected with these brushes.

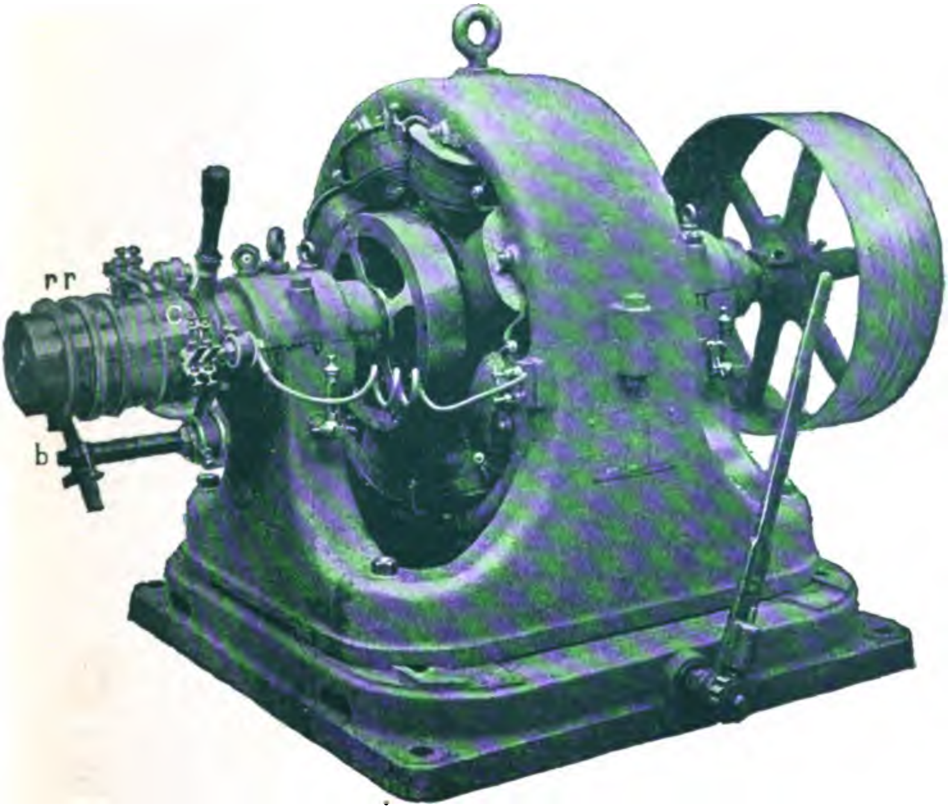


Fig. 140—Westinghouse 60 K. W. Single-Phase Alternator.

In addition to the collector rings, a commutator C, is provided for the purpose of supplying a portion of the field excitation sufficient to maintain the pressure under load; or, in other words, to *compound the machine.* The eight field-magnet coils receive nearly all their magnetizing current from a separate continuous-current machine, called the *exciter*, and this excitation is sufficient to produce the pressure of 1,100 or 2,200 volts, at no load, or with the main circuit of the machine open. When, however, the main circuit is loaded, and current is supplied by the machine, the pressure at the collector rings, or main terminals, would drop, were it not that an auxiliary winding on the field magnets, connected with the commutator C, receives a continuous current, which increases with the load, and thereby enables the pressure at the terminals to be kept constant.

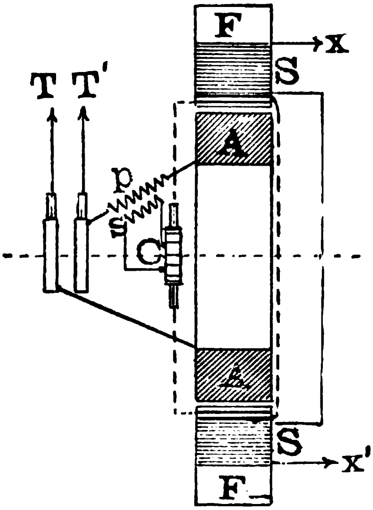


Fig. 141—Diagram of Connections Westinghouse Uniphaser.

The connections of the preceding machine are represented in the accompanying diagram, Fig. 141. It will be seen that in series with the armature A, is a coil p, in magnetic connection with a secondary coil s, so that, when a current is supplied by the armature to the main circuit, a secondary alternating pressure is induced in the coil s, connected to the segments of the commutator C. By this means, a continuous or direct current is supplied from the brushes on the commutator to the auxiliary winding on the field magnets. The main excitation is supplied to the field coils S, S, by the terminals X, X^1.

Fig. 142, shows the connections of a Westinghouse 10-pole alternator, indicating the positions of the commutator brushes, and their connection with the compound-wound magnets.

Fig. 143, shows the unwound field frame of a somewhat similar Westinghouse alternator of 45 K.W. capacity. In this machine the field frame is cast in one piece, while in the larger machine shown in Fig. 140, and in still larger sizes, the field frame is cast in two separate pieces. The field magnet cores are not solid masses of iron or steel, but are laminated masses, formed of a number of parallel plates of soft

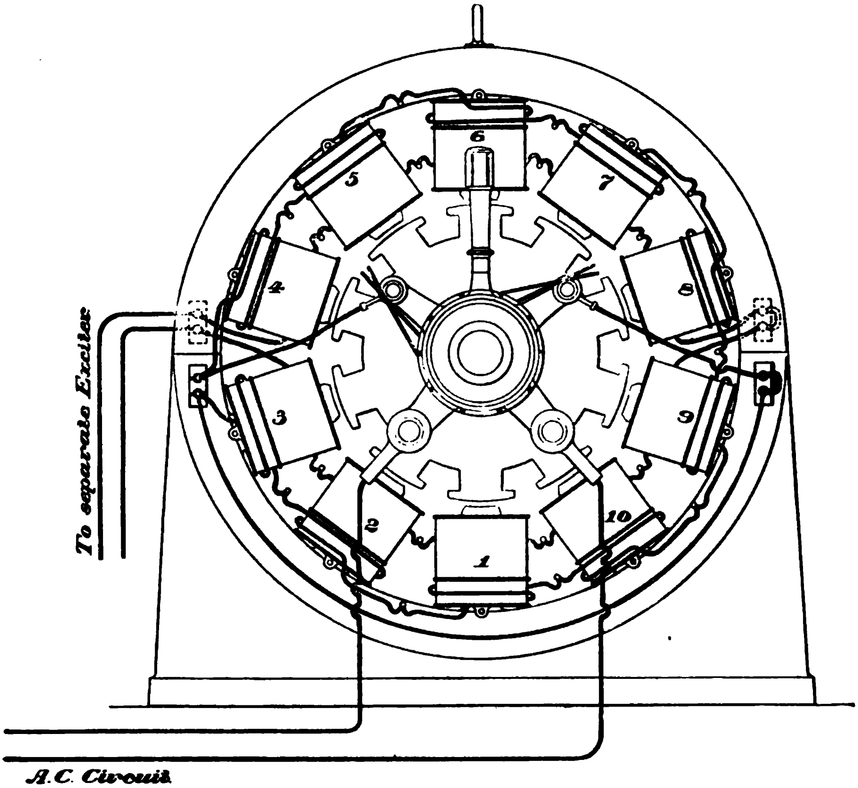


Fig. 142—Diagram of Connections for Westinghous Alternator.

steel which are clamped together and protected by comparatively stout end plates. The pole pieces so assembled are set in the mould in which the field frame is cast, and are thus rigidly connected with the field frame. The use of laminated pole pieces reduces the tendency to waste power by the formation of eddy currents in the field poles.

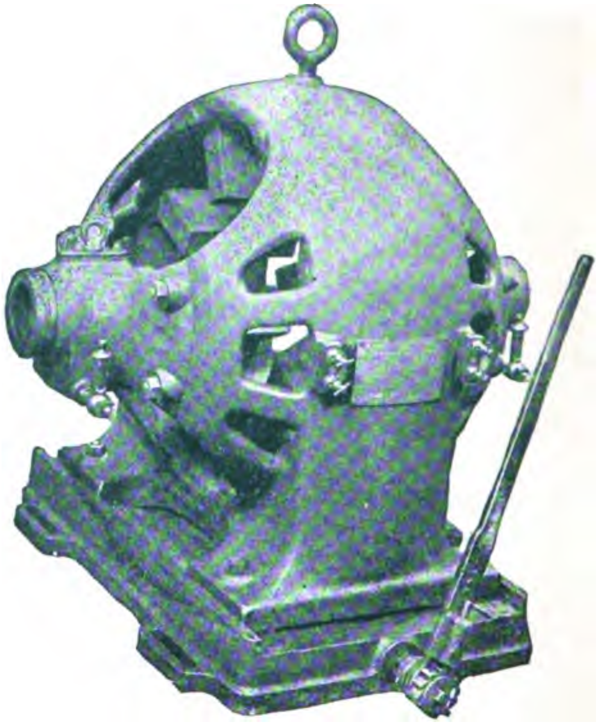
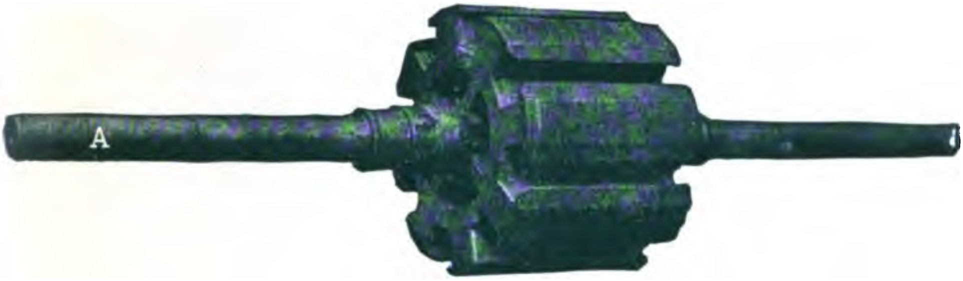
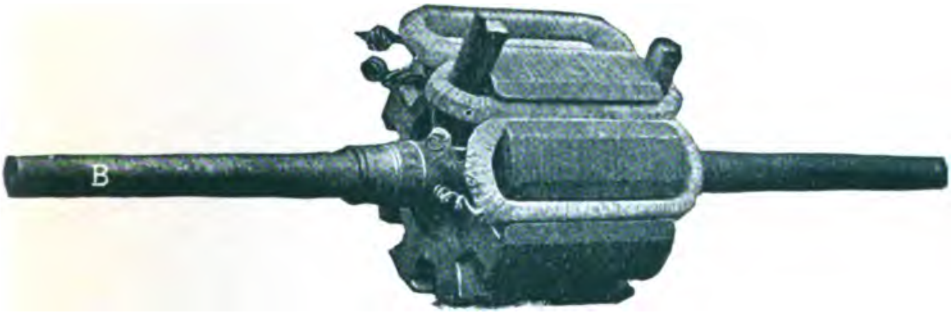


Fig. 143—Westinghouse Field of 45 K. W. Single-Phase Alternator.

The armature of the uniphaser shown in Fig. 143, is shown in Fig. 144. Here, it will be seen that the laminated core at A, is made up of a series of punched plates, forming, when assembled, a combination of eight heavy teeth or armature projections. The armature coils are slipped over these polar



Armature Core.



Armature Core—Methods of Placing Coils.

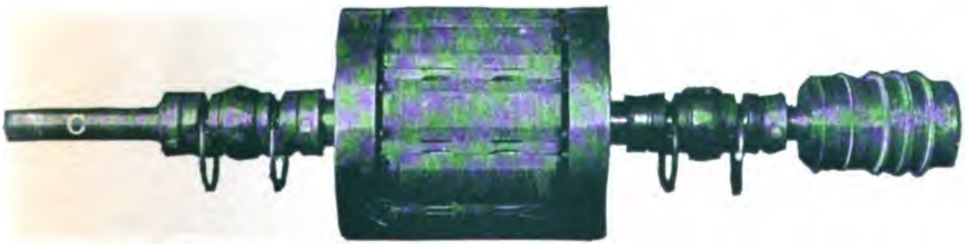


Fig. 144—Armature of Westinghouse Single-Phase Alternator in Process of Winding.

projections, as shown at B, and are then held firmly in place by suitable wooden wedges. The completed armature with

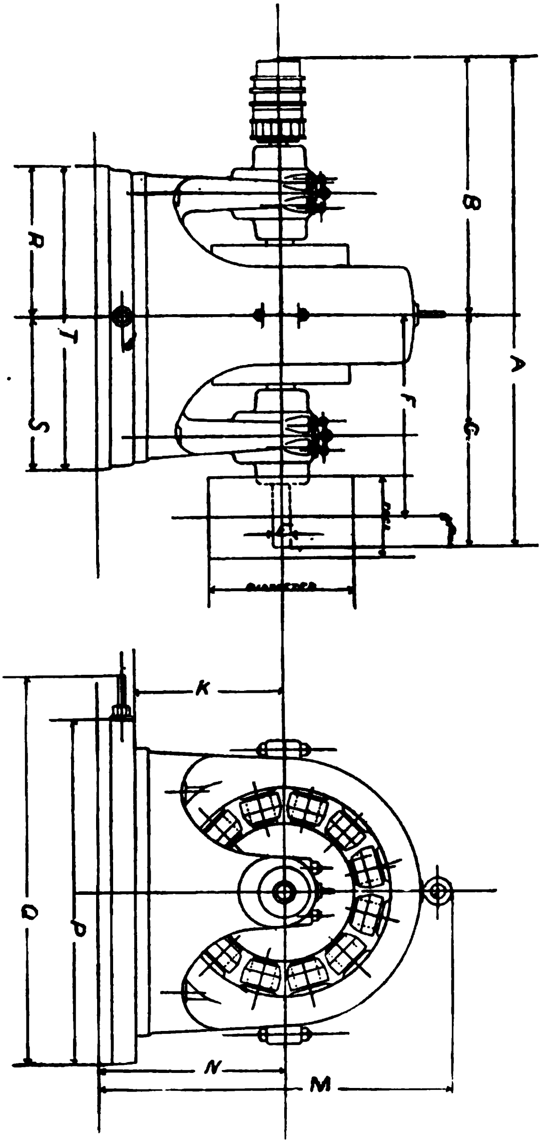


Fig. 145—Diagram to Table of Dimensions of Westinghouse Single-Phase Alternators.

its commutator, collector rings, and bearings, is shown at C. The wires connecting the armature coils with the collector rings are carried through a channel in the centre of the shaft. The coils for the compound-winding are placed on the spokes of the armature within the space between the projections of the laminated core and the shaft, and wires from the secondary coils to the commutator are also carried through the centre of the shaft.

Fig. 145, with the accompanying table, shows the dimensions and weight of these uniphasers between 60 and 150 K. W.

TABLE OF DIMENSIONS OF WESTINGHOUSE SINGLE-PHASE ALTERNATOR.

KW.	No. of Poles.	Alts.	Revs.	FIELD EXCITATION.		A	B	C	E	F	K	M
				Volts.	Amps.							
60	8	7200	900	125	8	65⅛″	34½″	30⅝″	2⅜″	27″	19½″	46⅞″
75	10	7200	720	125	8	73½	37⅝″	36⅛″	2⅞″	30⅜″	21¼″	52½″
150	12	7200	600	125	22	103⅛″	52″	51⅛″	3⅞″	44½″	24″	61½″

N	P	Q	R	S	T	PULLEY.			KEYWAY.		Weight Net Lbs
						Diam.	Face.	Length of Hub.	Width.	Depth.	
24⅞″	45⅜″	50⅛″	20 9/16″	20 9/16″	41⅛″	20″	11″	7″	⅝″	¼″	3,800
26¾″	51¾″	56¾″	22⅞″	22⅞″	45¾″	25″	15″	9″	¾″	5/16″	5,600
31½″	59¼″	64¼″	31⅜″	31⅜″	62¾″	33″	26″	13″	1″	⅜″	11,800

Fig. 146, shows a Wood 3,000-light compound-wound alternator, with 24 poles. It delivers 150 K.W., at 700 revolutions per minute, at a frequency of 140 cycles per second. Its pressure is either 1,000 or 2,000 volts. This machine is compounded to maintain its pressure under load, or, it may be over-compounded, so as to increase its pressure five per cent or ten per cent at full load. This enables the pressure to be maintained constant under load, at the end of a comparatively long feeder. The armature shaft has three bearings. The machine is provided with a small exciter driven by a small pulley and belt from the armature shaft as shown. There are two collector rings, and a commutator for the compound-winding. The brushes on the collector rings, as well as on the commutator, are doubled to ensure good contact.

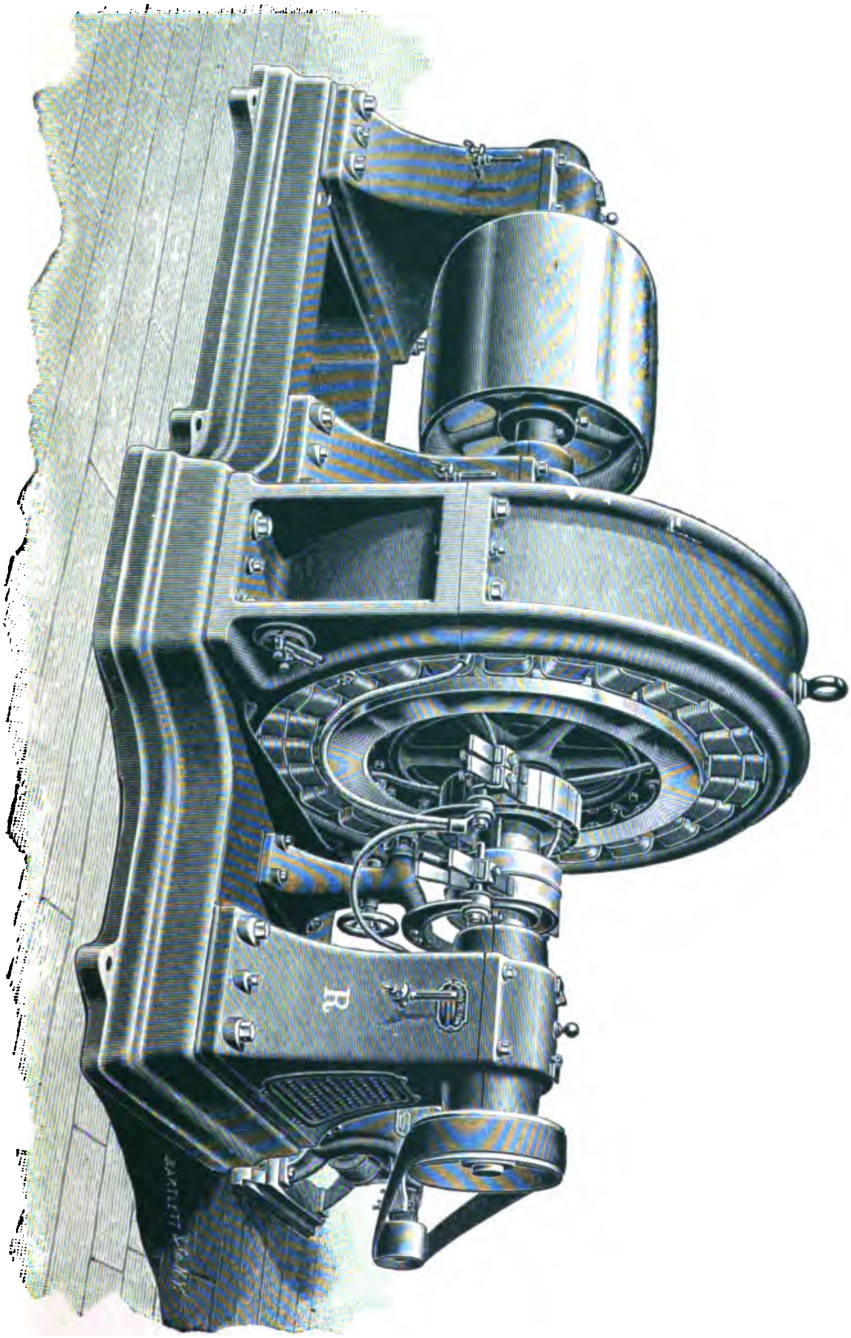
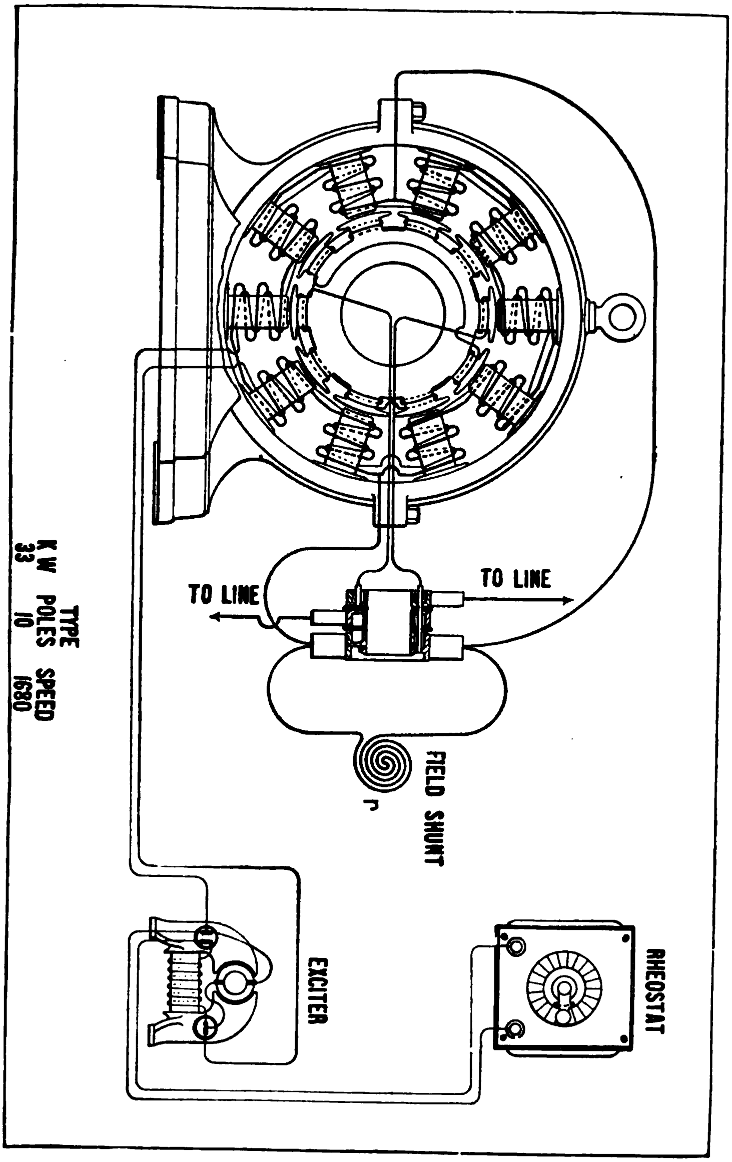


Fig. 146—"Wood" 3000-Light Compound Alternator.



TYPE

K W	POLES	SPEED
33	10	1680

Fig. 147—Connections for "Wood" Alternators.

The connections of the armature and field are shown in Fig. 147. Instead of bringing the two ends of the armature winding out at the same point, the coils are brought out at two additional points. This is done for the purpose of bringing the maximum pressure across a diameter instead of at adjacent coils. The exciter supplies the main winding of the field coils, while a portion of the armature current is rectified by the commutator and supplied to an auxiliary field-winding for compounding. The armature current passes through a resistance coil r, placed in the pedestal of the armature bearing.

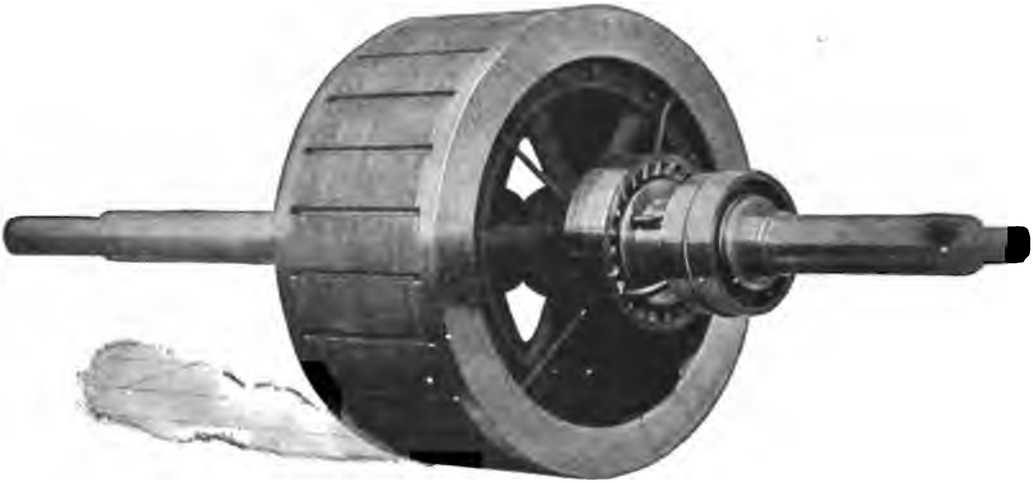


Fig. 148 –" Wood " 3000-Light Armature.

The armature of this machine, with its commutator and collector rings, is represented in Fig. 148. It has 24 laminated teeth, or polar projections, each of which is surrounded by its coils of wire.

The series field-shunt employed for compounding, consists of a strip rheostat, and is represented in Fig. 149.

The connections of a "Wood" 200-K.W. alternator are shown in Fig. 150. This machine has 24 poles and 24 armature polar projections, and makes 700 revolutions per minute.

The full pressure is developed in one quarter of the armature, so that there are four groups or quadrants of four coils each, connected in parallel. Thus, A,A, and B,B, are the armature poles. The opposite points, A,A, are connected to one collector ring *aa*. The opposite points B,B, are not connected directly to the other collector ring bb, but through the commutator, the brushes of which are permanently shunted by the field shunt. Part of the current passes through this resistance and part through the auxiliary winding on the field.

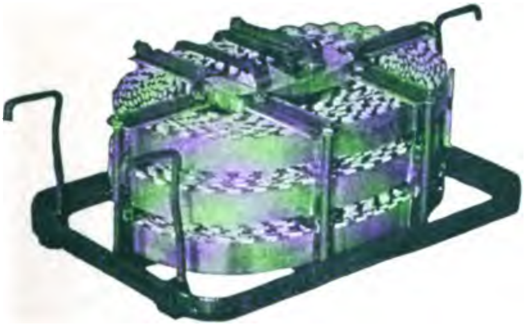


Fig. 140—"Wood" Series Field Shunt.

The accompanying table shows the dimensions and weights of these high-frequency alternators.

LIST OF "WOOD" HIGH-FREQUENCY ALTERNATORS. 140 CYCLES, 1,100 OR 2,200 VOLTS, FULL-LOAD.

Kilowatts.	Poles.	Revolutions per Minute.	Lights 16 C. P.	Horse Power Required.	Diameter of Pulley.	Face of Pulley.	Width of Belt.	Total Height.	Floor Space in Inches First Dimension Parallel to Shaft.	Weight of Armature.	Weight of Alternator Complete.	Type Number of Exciter Required.
33	10	1680	600	50	11	6	5	44	50 x 50	420	2300	00
50	12	1400	925	75	14	10	9	51	62 x 57	650	3500	0
100	16	1050	1850	150	18	15	14	62	83 x 70	1350	7500	21
200	24	700	3700	300	28	26	24	73	134 x 72	3500	18500	22
400	36	467	7400	600	40	50	48	98	185 x 96	7900	36600	23

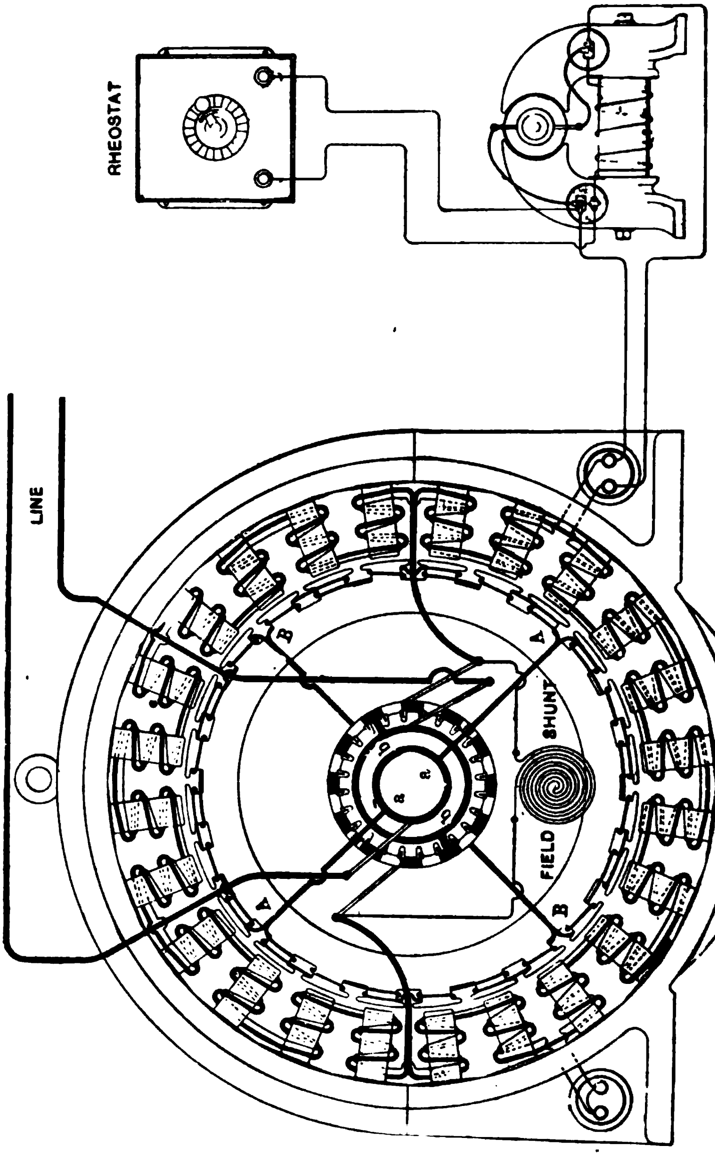


Fig. 150—Connections for "Wood" 200 K. W. Alternator.

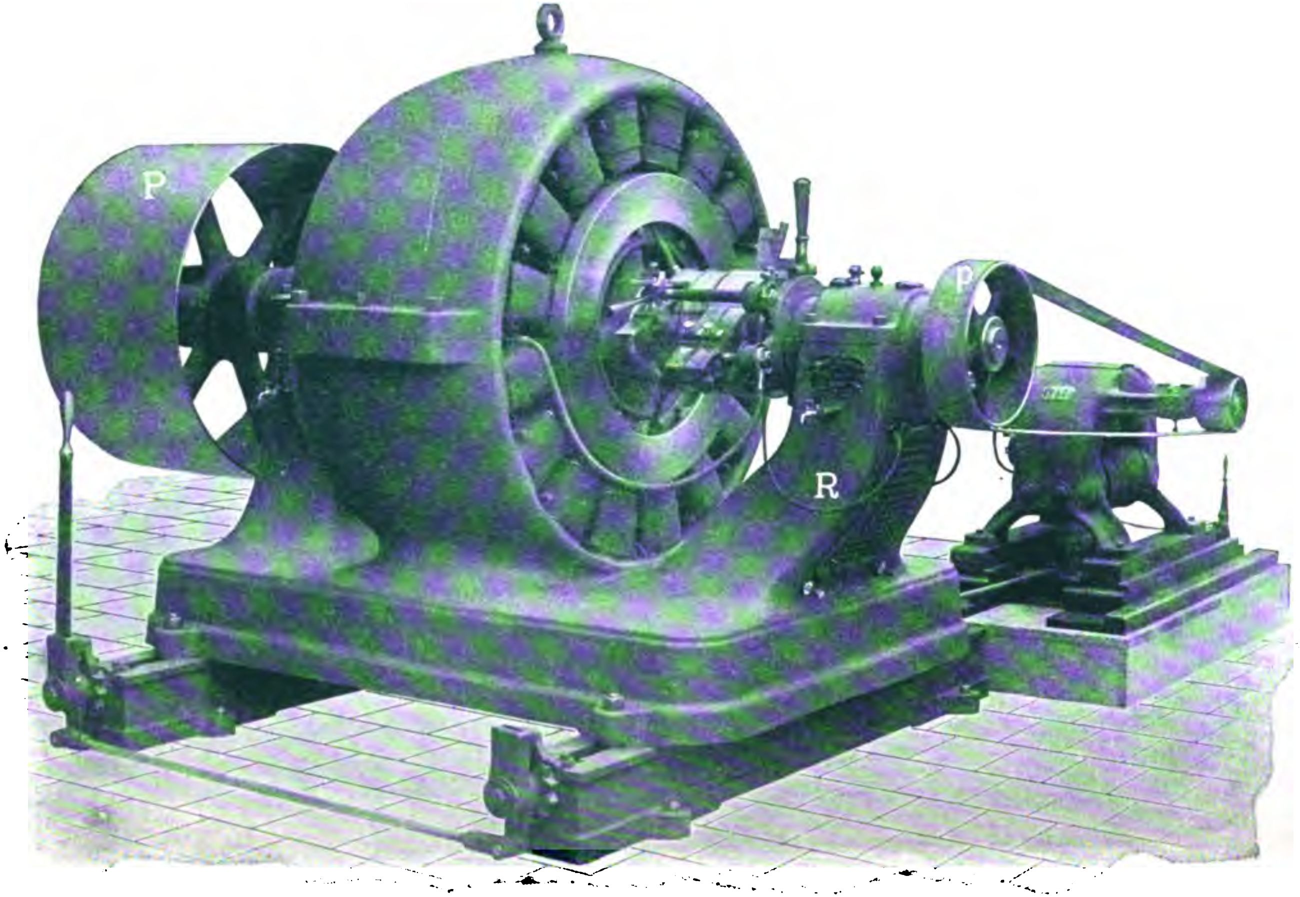


Fig. 151 "Wood" 150 K. W. 60 Cycles Alternator.

A Wood low-frequency alternator, of 150 K.W. capacity, is represented in Fig. 151. This machine has 16 poles instead of 24, as in Fig. 146. The general method of connections is the same in both classes of machines. In this machine, the handle for shifting the brushes on the commutator, so as to obtain a sparkless position of commutation, is above the commutator, while in Fig. 146, the handle was a small wheel placed beneath.

The sizes and weights of these low-frequency alternators is shown in the accompanying table.

LIST OF "WOOD" LOW-FREQUENCY ALTERNATORS. 60 CYCLES, 1,100 OR 2,200 VOLTS, FULL LOAD.

Kilowatts.	Poles.	Revolutions per Minute.	Lights 16 C. P.	Horse Hower Required.	Diameter of Pulley.	Face of Pulley.	Width of Belt.	Total Height.	Floor Space in Inches. First Dimension Parallel to Shaft.	Weight of Armature.	Weight of Alternator Complete.	Type Number of Exciter Required.
37½	8	900	700	56	20	7	6	50	64 x 53	825	3950	21½
75	12	600	1400	112	30	13	12	62	83 x 63	1700	7800	22½
150	16	450	2800	224	40	24	22	69	115 x 77	3450	15400	23½
300	24	300	5600	448	54	50	48	79	192 x 86	7800	35000	24½

One of the General Electric Company's single-phase alternators is represented in Fig. 152. This is a 10-pole belt-driven machine, delivering 60 K.W. at 1,500 revolutions per minute, and having, therefore, a frequency of 15,000 alternations per minute, or 125 cycles per second. The machine has a pair of collector rings, and also a commutator for commuting or rectifying a portion of the main armature current for the compound excitation of the field magnets. A resistance r, is placed in the main circuit as shown in Fig. 153. It will be seen that the current supplied by the armature passes partly through this resistance and partly through the auxiliary field winding, but in this case, the rheostat, r, is placed in a circular frame shewn beneath the commutator, and connected across its brushes, whereas in Figs. 147 and 150, the rheostat is placed in the pedestal.

Moreover, the resistance is inserted in the armature circuit at the middle point of its series-connected coils instead of at one extremity as indicated in Fig. 153, which represents diagrammatically the arrangement of connections. By this means the pressure connected to the commutator brushes and auxiliary field coils is greatly reduced.

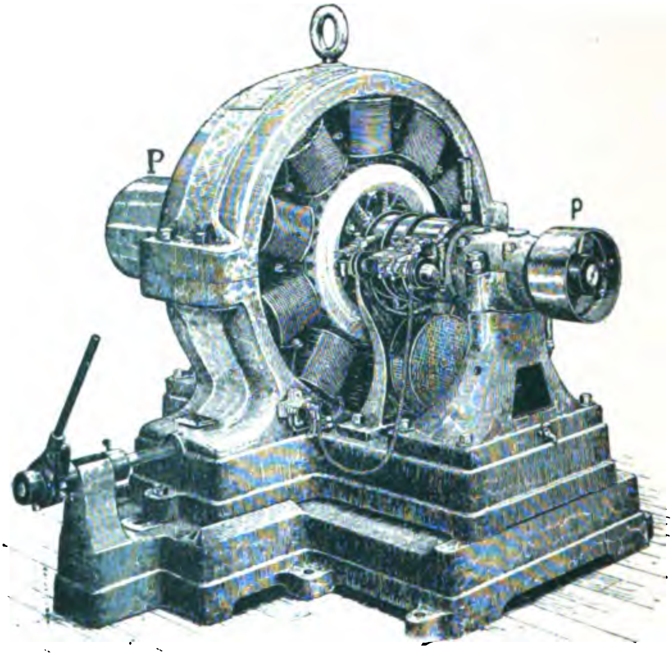


Fig. 152—"General Electric" Single-Phase Alternator.

The field frame of these machines is cast in two parts. The field coils are wound on spools of sheet iron, with brass or composition metal flanges. The spools are pinned to the field frame by steel pins. The compound field is usually arranged to over-compound ten per cent at full load.

The dimensions of these machines are shown in the accompanying table.

The exciter commonly employed with these generators is that shown in Fig. 45. The power of the exciter is usually

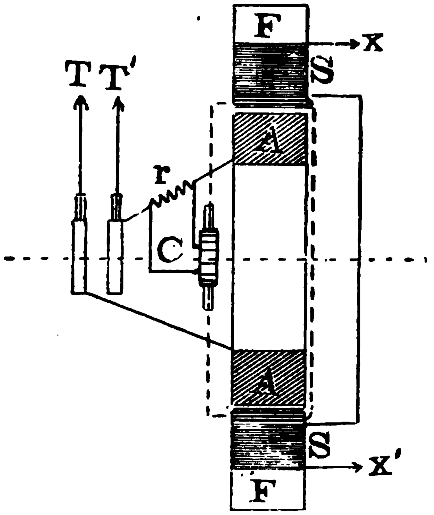


Fig. 153—Diagram of Connections of "General Electric" Uniphaser.

GENERAL ELECTRIC COMPANY'S ALTERNATING-CURRENT GENERATORS.
125 CYCLES PER SECOND.

Classification.				Volts No Load.	Volts Full Load.	Amps. Full Load.	Weight Lbs.	Floor Space.		Pulley.	
Type.	Poles.	K. W.	Speed.					Length over all.	Width.	Diam.	Face.
A	10	30	1500	1040	1150	26	2450*	49"	62"	13 "	7"
				2080	2300	13					
A	10	60	1500	1040	1150	52	3930*	64"	67"	13 "	11"
				2080	2300	26					
A	12	90	1250	1040	1150	78	7800§	80"	63"	15½"	15"
				2080	2300	39					
A	14	120	1070	1040	1150	104	9360*	86"	92"	18 "	18"
				2080	2300	52					
A	22	300	682	1040	1150	260	22138	152"	72"	28½"	35"
				2080	2300	130					

* With bedplate. § With rails.

about 1.5 per cent of the power of the generator, a one-K.W. machine being, however, the smallest used. The exciter is almost invariably wound for a full-load pressure of 125 volts. Fig. 154, shows the connections of these machines. Each has its own shunt-field rheostat. The dimensions of these exciters is given in the accompanying table.

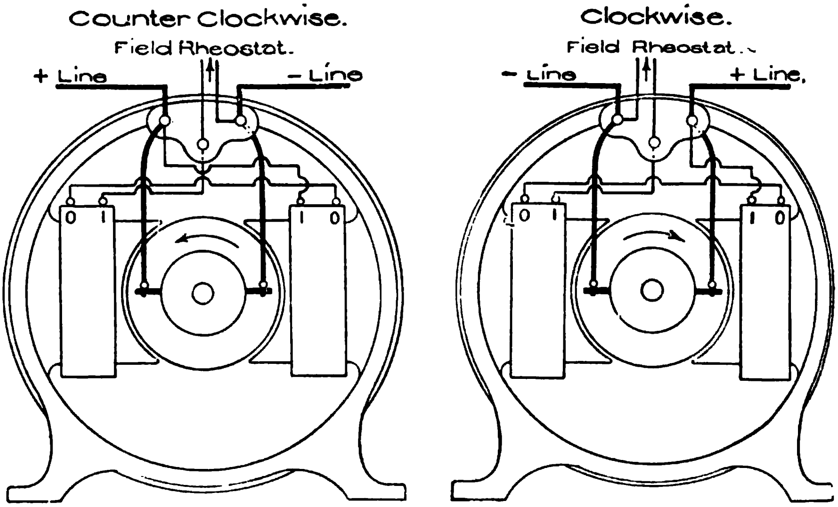


Fig 154—Connections for "General Electric" I. B. Exciters.

GENERAL ELECTRIC EXCITERS FOR ALTERNATORS.

		I. B. Exciter.				
Alternator.	Exciting Current.	Classification.	Floor Space.	Pulley.		Driving Pulley.
		Poles. K. W. Speed.		Diam.	Face.	Diam.
A 30	4.5	2–1.5–1900	19⅜" x 14⅝"	6⅜"	2½"	8¼"
A 60	4.5	2–1.5–1900	19⅜" x 14⅝"	6⅜"	2½"	8¼"
A 90	7.0	2–1.5–1900	19⅜" x 14⅝"	6⅜"	2½"	9¾"
A 120	8.0	2–1.5–1900	19⅜" x 14⅝"	6⅜"	2½"	11¼"
A 300	23.0	2–4.5–1800	30¼" x 19 "	6¾"	3 "	18 "
AM 100	11.0	2–1.5–1900	19⅜" x 14⅝"	6⅜"	2½"	9¾"
AM 150	18.0	2–2.5–1900	22 " x 15 "	6⅜"	2½"	17 "

A type of General Electric Company's single-phase alternator, in which 12 field-magnets in one frame are revolved by the pulley, and the armature is a stationary frame surrounding them, is shown in Fig. 155. This machine is separately excited. It delivers 150 K.W., at 60 volts pressure. Its speed is 600 revolutions per minute, and, consequently, its frequency is 7,200 alternations per minute, and the machine is so designed that on short-circuit, with full field excitation, the current strength can only increase 15% above full load.

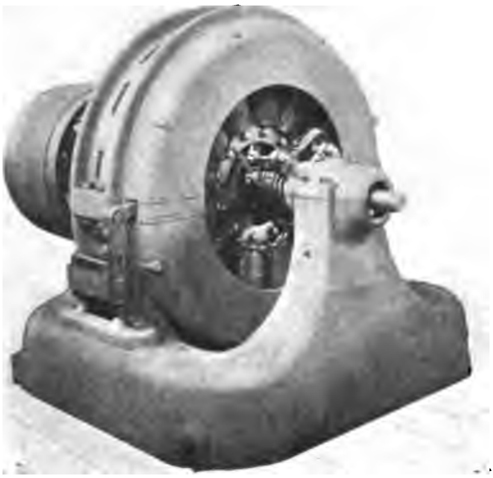


Fig. 155—"General Electric" Single-Phase Alternator.

Fig. 156, shows a Royal Electric Company's single-phase alternator. In this machine, the field-magnet core is rotated, or forms what is called the *rotor*, while the armature is stationary, or forms what is called the *stator*. The armature A, is supported by a central pair of pedestals S. The pole pieces n, n, n, and s, s, s, are revolved by the pulley P, on the main shaft, the pulley p, being employed to drive the exciter.

The armature, or stator of this machine, is represented separately in Fig. 157. The core is formed of 18 bars of iron, laminated circumferentially, or in the direction of rotation. At each end of each of these bars is an insulated coil. These coils may be connected together in a variety of ways. When all the coils on each side of the armature are connected in series, and the two sides are then coupled in series, the entire combination has a pressure in the standard machine of 2,200 volts. Pressures of 1,100, 550, 220, or 110 volts, can be obtained by

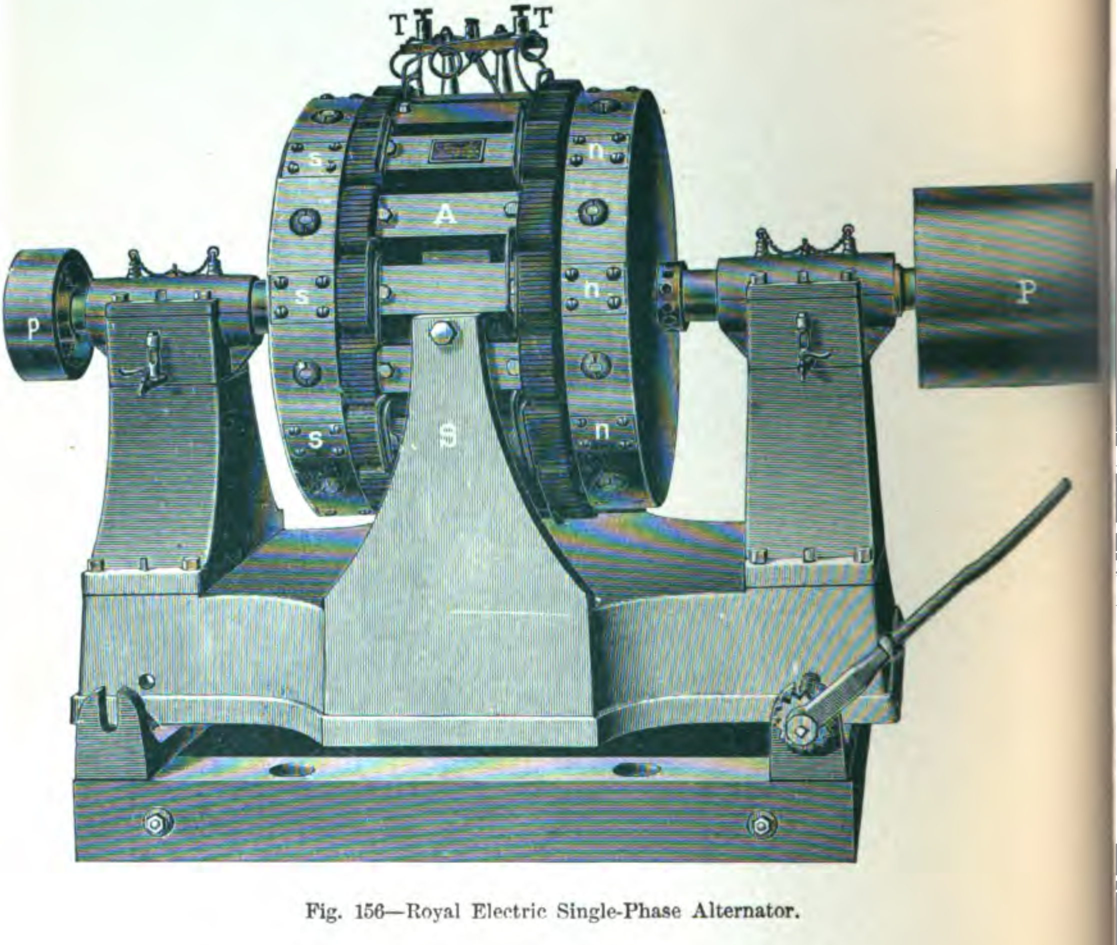


Fig. 156—Royal Electric Single-Phase Alternator.

suitable connections. T, T, are the main terminals of the armature, which are connected to the distribution lines.

The revolving field-magnet core, or rotor, employed with this machine, is represented in Fig. 158. It consists of a magnet core over-wound by a single coil rigidly supported over the hub M, M. In this machine no copper wire is rotated, the currents being induced by the motion of a mass of

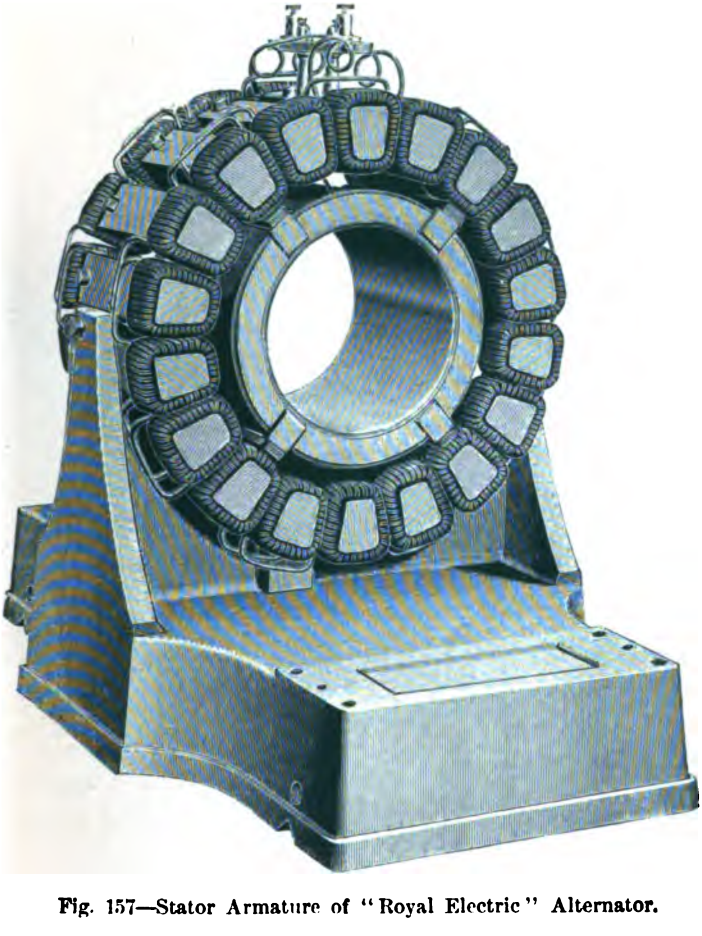


Fig. 157—Stator Armature of "Royal Electric" Alternator.

iron carrying the pole-pieces. Such an alternator is called an *inductor alternator*. From one end of the magnet core projects a star-shaped pole piece n, n, n, with nine projections or pole-pieces. From the other end of the core project an equal number of pole-pieces s, s, s, of opposite polarity. The intervening spaces between contiguous polar projections are filled with wooden blocks, so as to present a uniform

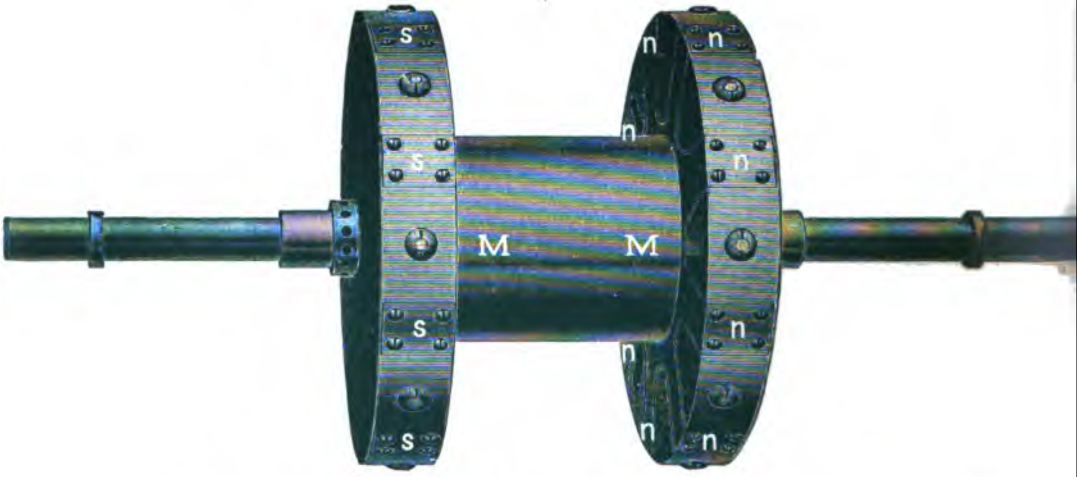
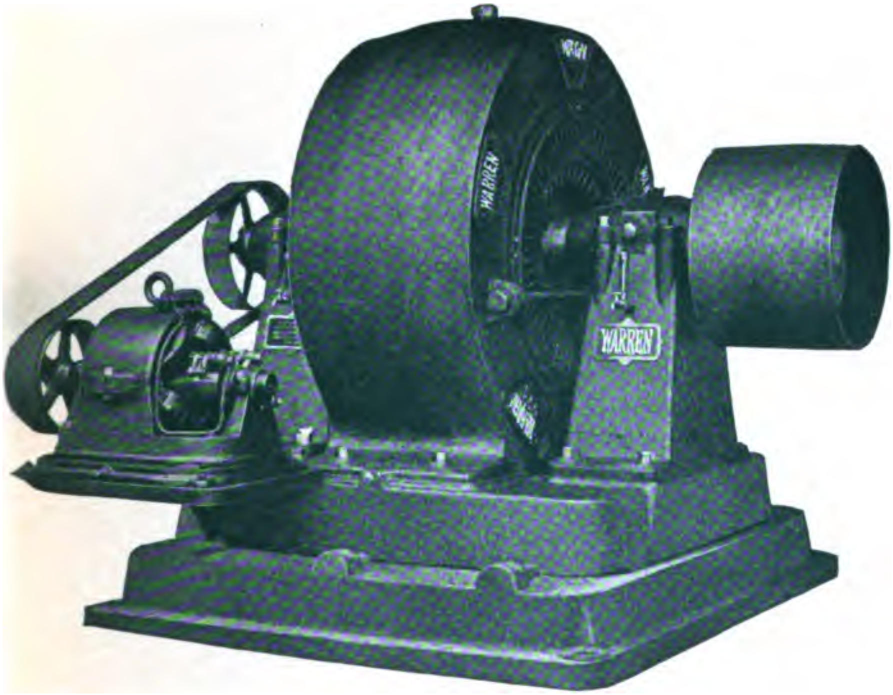


Fig. 158—Field Magnet Core or Rotor of "Royal Electric" Alternator.

Table of Dimensions of Royal Electric Company's Alternating-Current Dynamos.

Capacity in 16 C. P. Lights.	Capacity in Kilowatts.	Speed R. H. M.	Diameter of Pulley.	Width of Belt.	Floor Space in Inches.	Approximate Weight in Pounds.
500	25	1100	13	9	41 x 62	3000
650	32½	1100	14	11	41 x 67	3400
750	37½	1100	16	12	45 x 72	4000
1000	50	950	18	14	48 x 80	6000
1250	62½	860	20	15	48 x 86	7200
1500	75	860	22	17	56 x 92	8500
2000	100	700	24	20	56 x 98	10000

smooth surface to the surrounding air, and avoid the humming sound which would otherwise be produced by the revolution of the star-shaped mass. Since but a single magnetizing coil is required for the excitation of the multipolar field, the power required for excitation is comparatively small, and a comparatively small exciter is therefore needed.



Fig, 159—Warren 75 K. W. Alternator.

The accompanying table gives the principal dimensions of these alternators.

Fig. 159, shows the Warren Electric Manufacturing Company's belt-driven alternator, of 75 K. W. capacity.

Fig. 160, shows a longitudinal section of a 30 K.W. Warren alternator of this type. G, G, is the stationary armature frame or stator, with fixed laminated polar projections A, A, around which are secured the armature coils C, C. The steel hub, or rotor, H, carries laminated polar projections D, D, so that there are two air-gaps in the magnetic circuit, one between A and D, and the other between G and H. F, F, is the single magnetizing coil. Consequently, all the projections D, D, have one polarity, and all the projections A, A, have the opposite polarity.

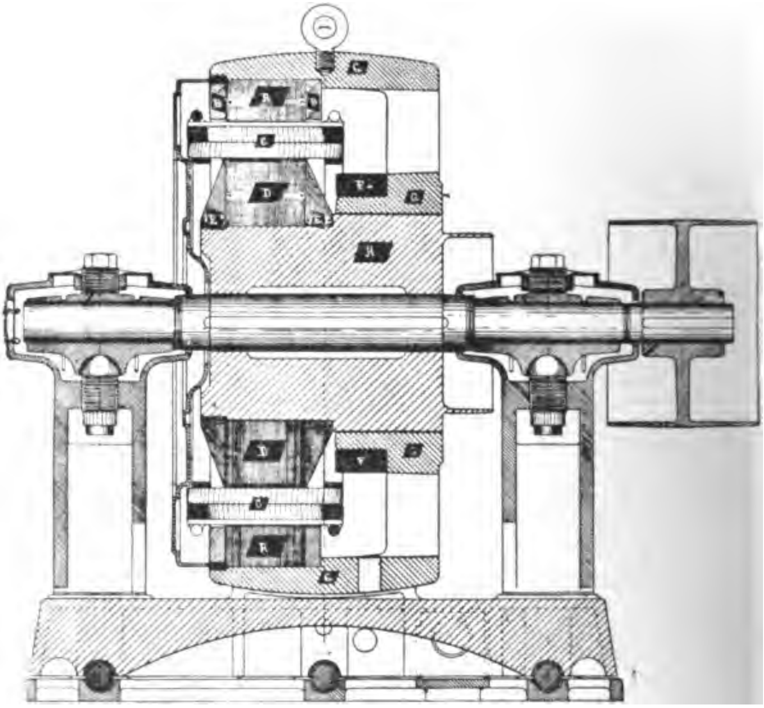


Fig. 160—Longitudinal Section of Warren Alternator.

This machine also belongs to the inductor type, since no copper wire is revolved.

Fig. 161, represents a 1500-light Walker Electric Company's Uniphase Alternator. This machine which is belt-

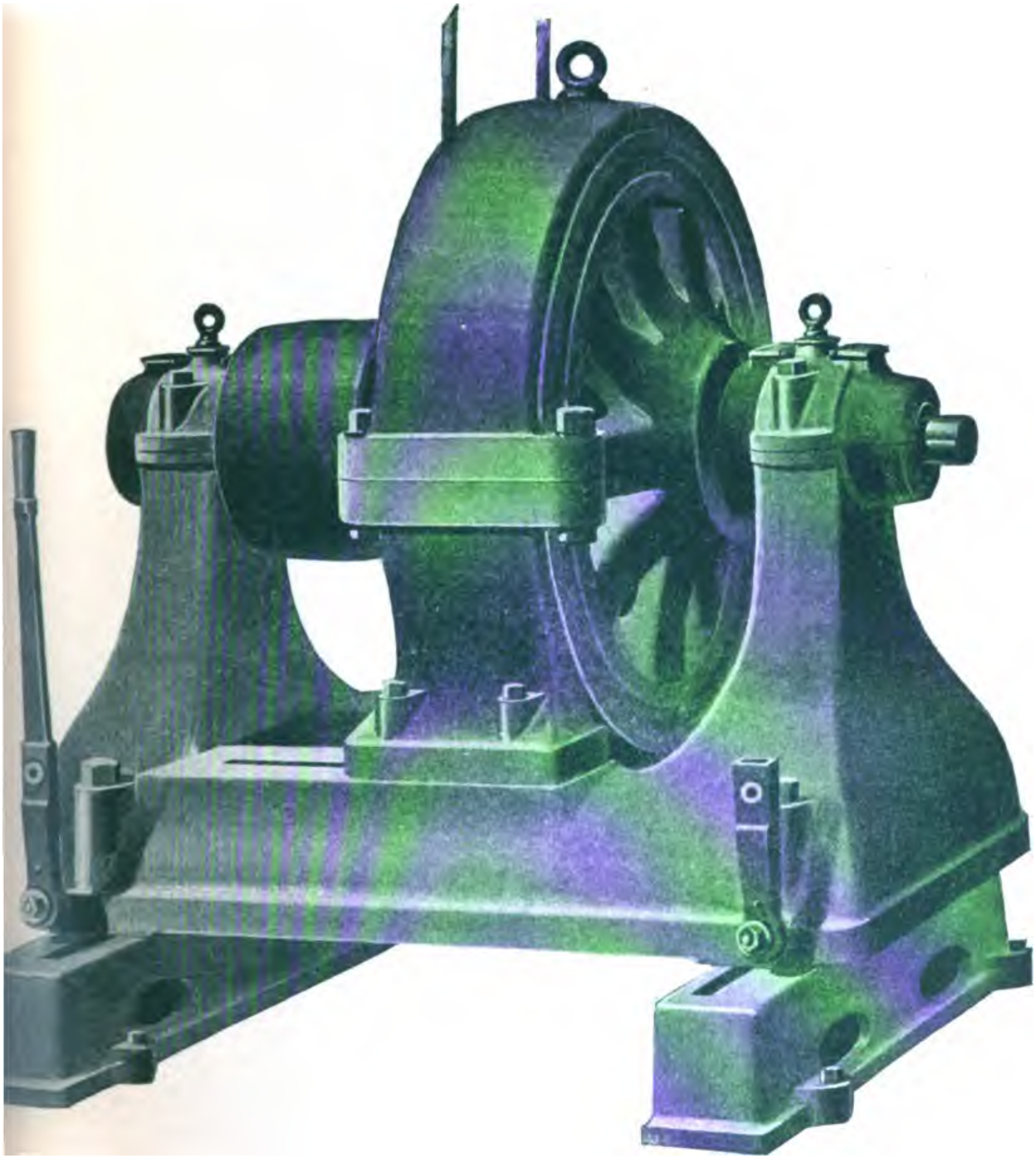


Fig. 161—1500-Light Walker Alternator.

driven, has two pedestals and the driving pulley is inside the pedestal.

Fig. 162, shows a Crocker-Wheeler Electric Company's 96 K. W. alternator for calcium-carbide furnaces. It delivers 1,600 amperes at about 70 volts pressure. It weighs about 6 tons. It is separately excited, and runs at about 800 revolutions per minute. Its frequency is about 27 cycles per second.

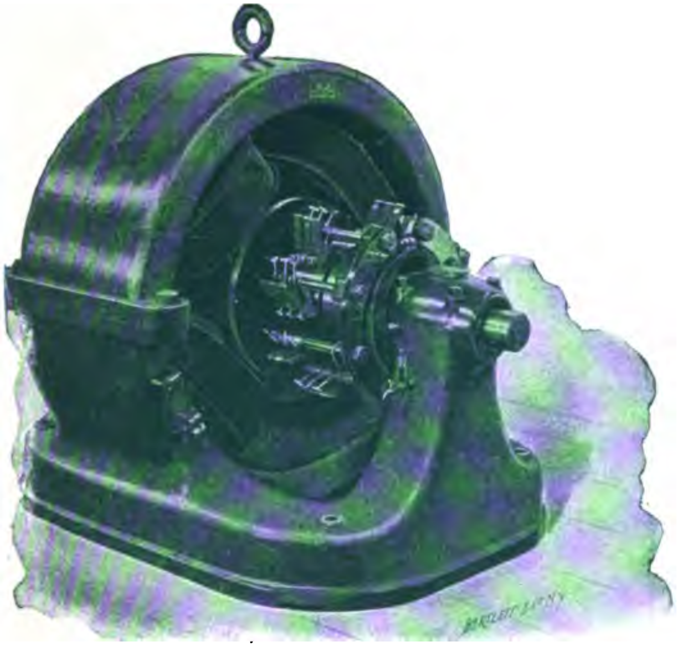


Fig. 162—Crocker-Wheeler Size 90, Separately-Excited, Low-Frequency, Alternating-Current Dynamo.

CHAPTER VIII.

MULTIPHASE ALTERNATORS.

A *multiphase alternator* is an alternator which not only delivers more than one alternating current, but, moreover, delivers this plurality of alternating currents in phases which differ from one another by a definite amount. Thus, a *triphase alternator*, or *triphaser*, delivers three alternating currents which differ in phase by one-third of a cycle. Thus, in Fig. 163, if 1, 2 and 3, are three wires carrying the three-phase currents generated by the rotation of the armature, with its three coils, 1, 2, 3, in the bipolar field N, S, then it will be evident, that since the current generated by any one coil, say 1, completes a cycle, or to-and-fro electric impulse, in a single revolution, the current generated by the coil 1, will be one-third of a cycle in advance of that generated by the coil 2, and this, in its turn, one-third of a cycle in advance of that generated by the coil 3. Consequently, the currents in the three wires 1, 2 and 3, differ in phase one from another by one-third of a cycle.

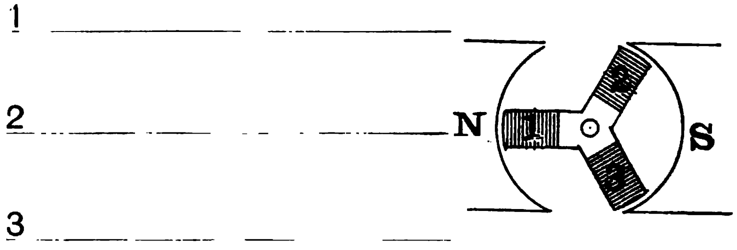


Fig. 163—Diagram of Three-Phase System.

In a similar manner, in a two-phase system, if 1, 2, Fig. 164, represent two wires, receiving two-phase currents from the two coils 1, 1, and 2, 2, of the bipolar alternator, N, S, it will be evident that because the coil 1, 1, is one-quarter of a cycle, or 90°, ahead of the coil 2, 2, the current it will deliver to the wire 1, will be one-quarter of a cycle ahead of the current delivered by the coil 2, 2, to the wire 2. Consequently, when the current waves are at their crests, or maximum strengths, in one wire, say 1, they will be at their minimum strengths, or at zero, in the other wire, 2.

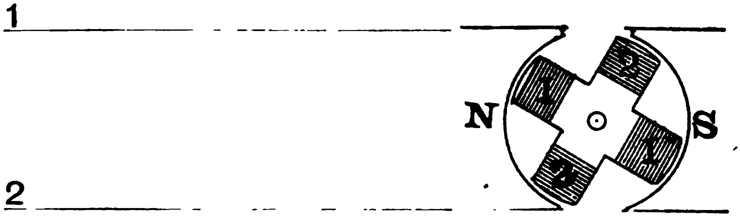


Fig. 164—Diagram of Two-Phase System.

Multiphase systems have recently come into extended commercial use, owing to the convenience they offer for the electric transmission of power ; for, as we shall see subsequently, multiphase motors are very simple, both in their construction and operation.

Fig. 165, shows a Westinghouse composite type of belt-driven two-phase, or diphase generator. Here, as in most diphase alternators, there are two pairs of collector rings, one pair for each circuit and phase. The machine shown is a 75 K.W. generator, and is usually wound for either 1,000 or 2,000 volts. It is a compounded machine, being mainly excited by a separate exciter not shown in the figure, as well as by rectified currents supplied by means of the commutator from an auxiliary winding. The connections between the armature and the external circuit, together with the compound winding, are shown in Fig. 166. A A, is a closed-circuit armature winding which is tapped at four equidistant points, 1, 2, 3 and 4. These points are 90° apart, and are led to the four collector rings through two primary coils wound upon the internal spokes of the armature. A secondary winding is placed, as shown, in magnetic connection with both primaries, and in which an alternating pressure is generated in proportion to the strength of the main armature currents. The commutator has the

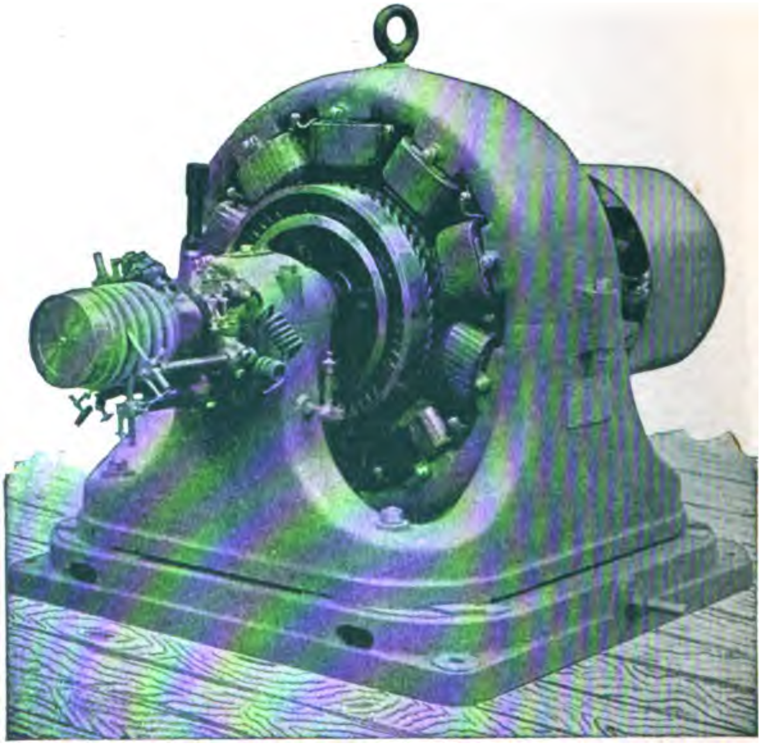


Fig. 165—Westinghouse 75 K. W. Two-Phase Generator.

brushes resting upon it, which carry off the rectified current to the auxiliary field. The brushes resting on the collector rings are connected to the four line wires 1, 2, 3 and 4. Between 1 and 3, and also between 2 and 4, there exists a pressure of 2,000 volts, since this represents the pressure across diameters of the armature. Between neighboring

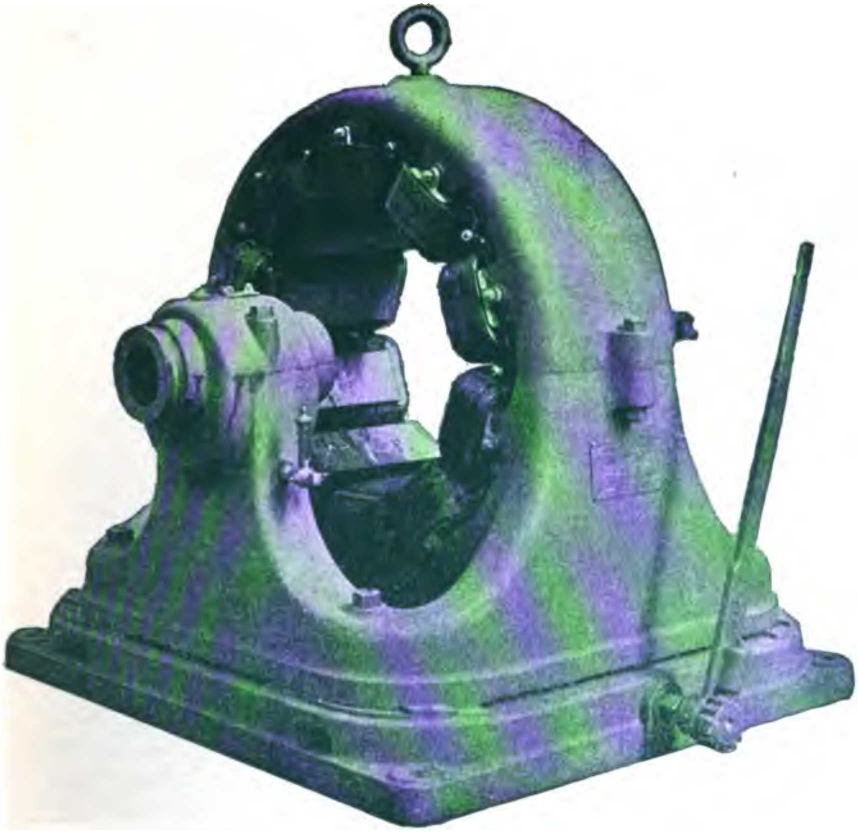


Fig. 167—Field of 75 K. W. 60-Cycle Westinghouse Two-Phase Generator, Showing Field-Coils in Place.

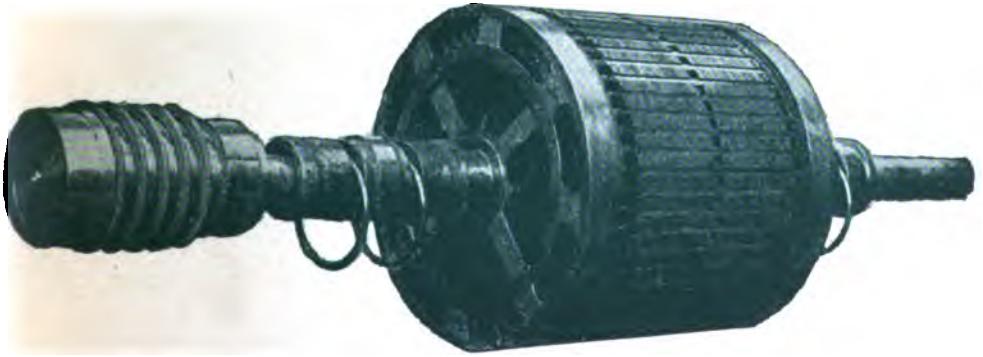


Fig. 168—Armature of 75 K. W. Westinghouse Two-Phase Generator.

conductors 1 and 2, 2 and 3, or 3 and 4, there is a pressure of about 1,400 volts. Fig. 167, shows the field and Fig. 168, the armature of this generator. It will be seen that there are 10 poles. Since the speed of revolution is 720 revolutions per minute, the frequency will be 7,200 alternations per minute, or 60 cycles per second, in each main circuit, the two currents being out of step by one-quarter of a cycle. It will be observed that the armature is toothed, but has a *distributed winding*, that is to say, the winding is distributed over its surface and not wound in coils around polar projections.

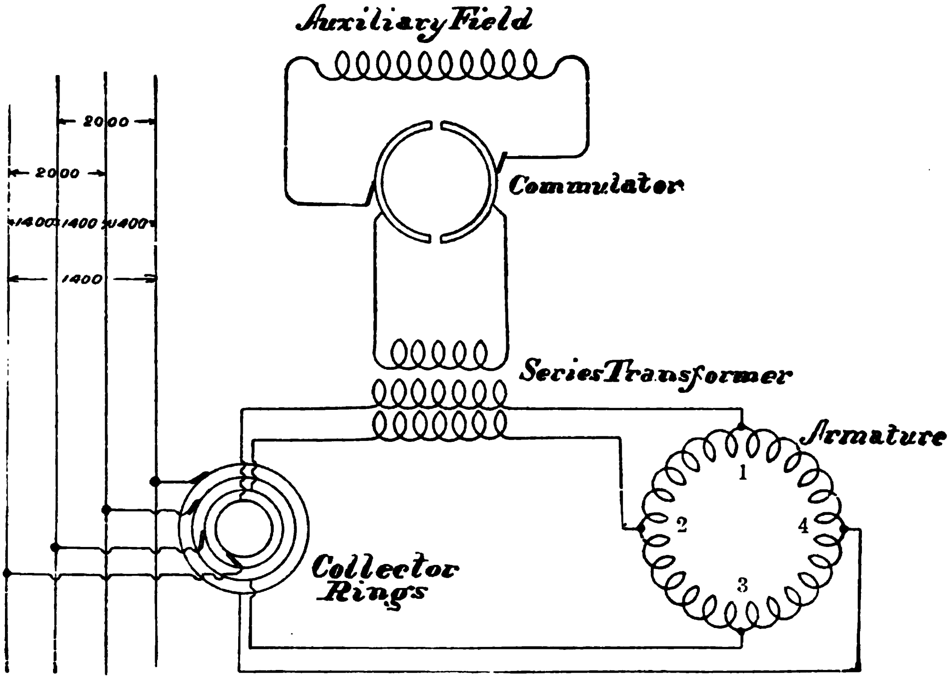


Fig. 166—Diagram of Connections for "Westinghouse" Two-Phase Generator.

The dimensions of these machines, in the most common sizes, are indicated in Fig. 169, by reference to the accompanying table.

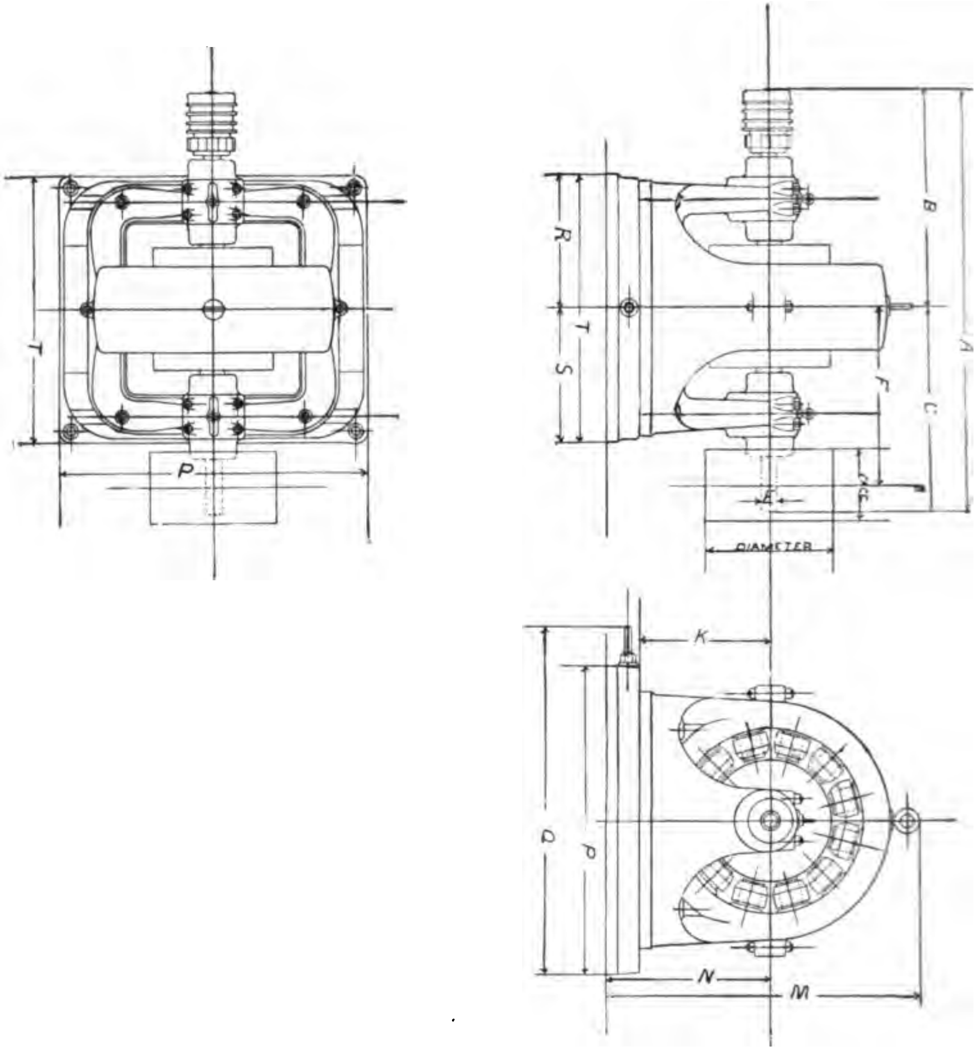


Fig. 169—Dimensions of "Westinghouse" Standard Polyphase Generators.

Fig. 170, is a diagram of the circuit connections of a diphaser. Four wires, 1, 2, 3 and 4, run from the machine. At A, two transformers are installed T_1, and T_2. These transformers reduce the 2,000-volt pressure between wires 1 and 3, and 2 and 4, to 100 volts in their secondaries. The secondary of T_1 is connected to an incandescent lamp circuit L_1. The secondary of T_2 is connected to an arc-light circuit A_2. Single-phase currents flow in each of these secondary circuits, but these single-phase currents differ in phase by a quarter cycle. The two secondaries, however, are jointly led to the three terminals of a two-phase motor M, and by this means, two-phase currents are supplied to the motor for its operation. Similar connections are shown at B, except that the intermediate primary pressure of 1,400 volts is employed in combination for the operation of the diphase motor m, while the single-phase pressure of 2,000 volts between wires 1 and 3, is reduced to a single-phase pressure of 100 volts for

TABLE OF APPROXIMATE DIMENSIONS OF WESTINGHOUSE POLYPHASE GENERATORS.

KW.	No. of Poles.	Alts.	Revs.	Field Excitation. Volts.	Field Excitation. Amps	A	B	C	E	F	K	M
45	8	7200	900	125	6	62¼″	31⅜″	30⅞″	2⅜″	26½″	17 ″	42⅜″
60	8	7200	900	125	7	65⅞″	34¾″	31⅛″	2⅞″	27 ″	19½″	47⅞″
75	10	7200	720	125	10	75¼″	37½″	37¾″	3⅜″	30⅝″	21¼″	53 ″
100	10	7200	720	125	9	91⅝″	44⅝″	47 ″	4⅜″	40½″	29 ″	65⅜″
150	12	7200	600	125	22	104⅞″	50½″	54⅜″	4⅛″	45⅝″	24½″	63½″

N	P	Q	R	S	T	Pulley. Diam.	Pulley. Face.	Pulley. Length of Hub.	Keyway. Width.	Keyway. Depth.	Weight. Net Lbs.
21 ″	41¼″	45⅞″	17 13/16″	19 5/16″	37⅛″	20″	9″	6″	⅜ ″	¼″	3,800
24⅞″	45⅞″	50⅛″	20 9/16″	20 9/16″	41⅛″	20″	11″	7″	¾ ″	¼″	4,700
26¾″	51¾″	56¾″	22⅞ ″	22⅞ ″	45¾″	25″	15″	9″	1 ″	⅜″	6,300
34 ″	64½″	70 ″	34¼ ″	27¼ ″	61½″	25″	17″	12″	1 1/16″	11/32″	10,400
32 ″	59¼″	64¼″	31⅜ ″	31⅜ ″	62¾″	33″	26″	13″	1 ″	⅜″	14,000

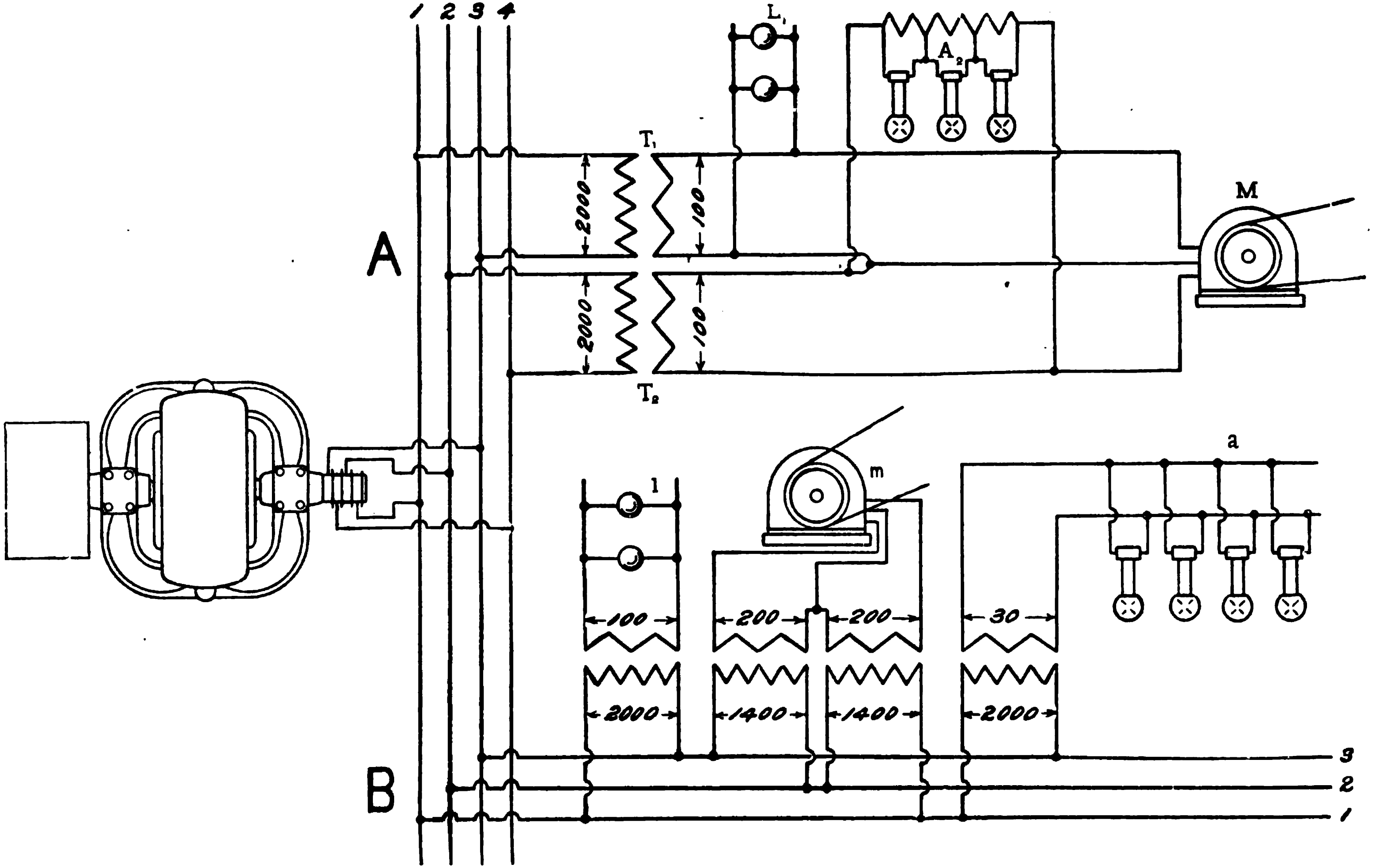


Fig. 170—Diagram of Circuits from a "Westinghouse" Two-Phase Generator.

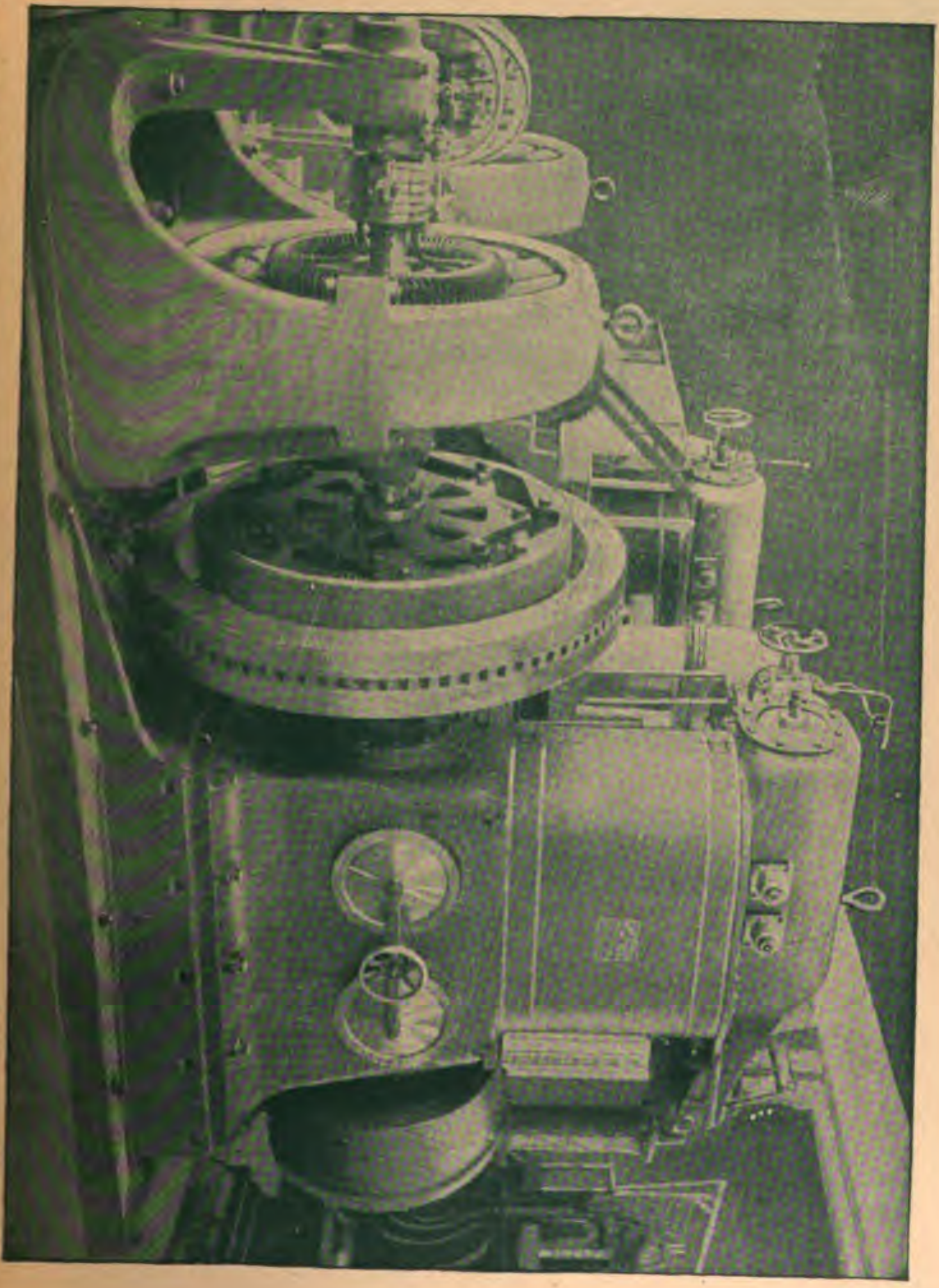


Fig. 171.—"Westinghouse" Two-Phase Generator Directly Connected Through a Flexible Coupling to a "Westinghouse" Engine.

incandescent lamps l, and reduced to a single-phase pressure of 30 volts for arc lamps a.

Fig. 171, shows a Westinghouse two-phase generator directly connected through a flexible coupling to a Westinghouse engine. It is a 375 K.W. generator, has 14 poles in its field frame, and runs at 215 revolutions per minute. The frequency in each circuit is 3,000 alternations per minute, or 25 cycles per second. This generator is situated in the power-house of the Westinghouse Company's works at East Pittsburgh, and delivers current at 200 volts pressure for

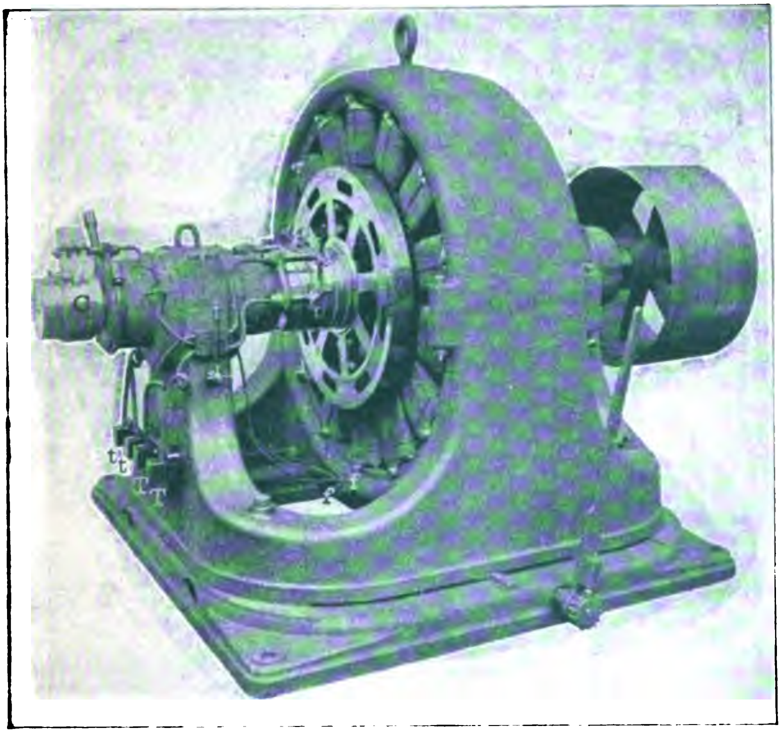


Fig. 172—"Westinghouse" 180 K. W. Two-Phase Belt-Driven Generator.

distribution to motors throughout the works without the interposition of transformers.

The low frequency of 25 cycles-per-second is employed in some cases as suitable for operating alternating-current motors.

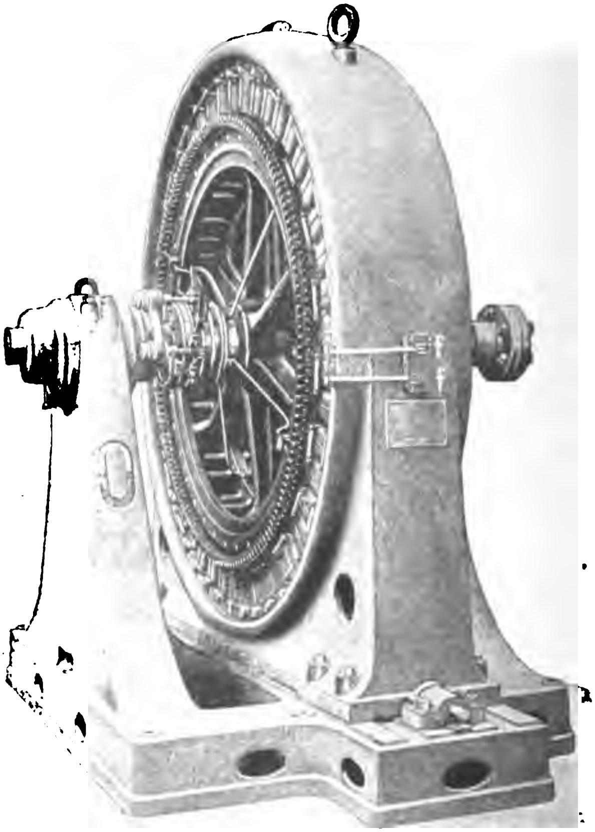


Fig. 173—"Westinghouse" 650 K. W. Two-Phase Generator.

A Westinghouse Electric and Manufacturing Company's 180 K.W. diphase belt-driven generator is shown in Fig. 172.

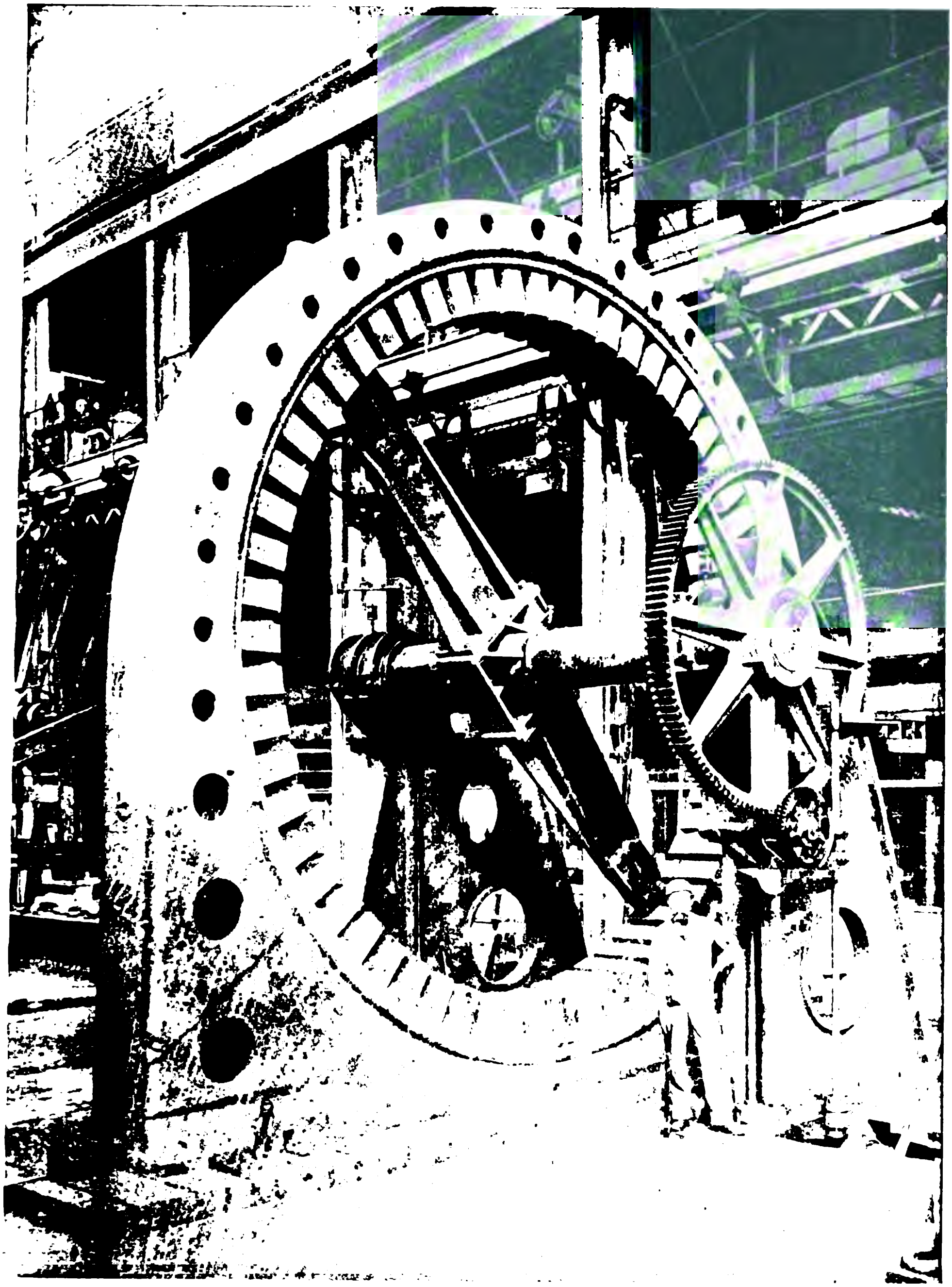


Fig. 175—Boring Field of 1500 K. W. 2-Phase Engine Type Generator.

The armature has four collector rings connected to the main terminals T, T, t, t. f f, are the terminals of the compounding field coils, which are supplied from the brushes resting on the commutator C. The armature of this machine has 76 slots, and the field has 14 poles. Within the armature are the series transformers, by means of which the pressure at terminals is automatically maintained under load.

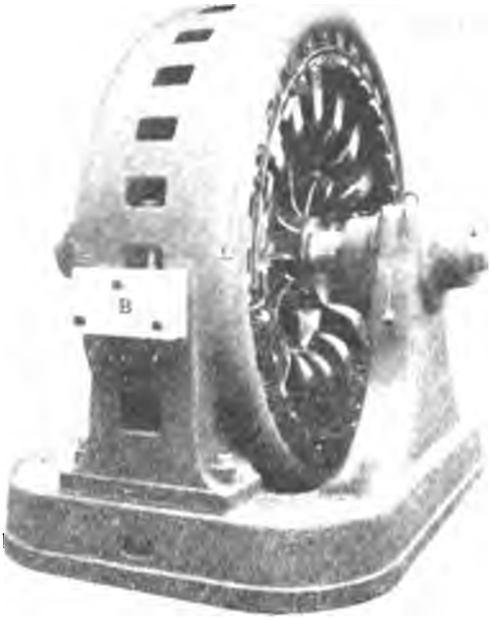


Fig. 174—"Westinghouse" 225 K. W. Tri-Phase Inductor Generator.

A larger diphase Westinghouse generator is shown in Fig. 173. This is a 650 K. W. machine with 46 poles, f f being the field terminals. The armature connections are made with the collector rings through four strap conductors placed at quadrants.

Fig. 174, shows a Westinghouse Electric and Manufacturing Company's 225 K. W. tri-phase inductor-generator. Here the motor consists of a polar frame, magnetized by a single magnetizing coil.

The operation of boring out the field frame of a Westinghouse 1,500 K. W. alternator of the engine type, is shown in Fig. 175. A chip is taken off by each end of the long cutter arm, to expedite the work and balance the stresses.

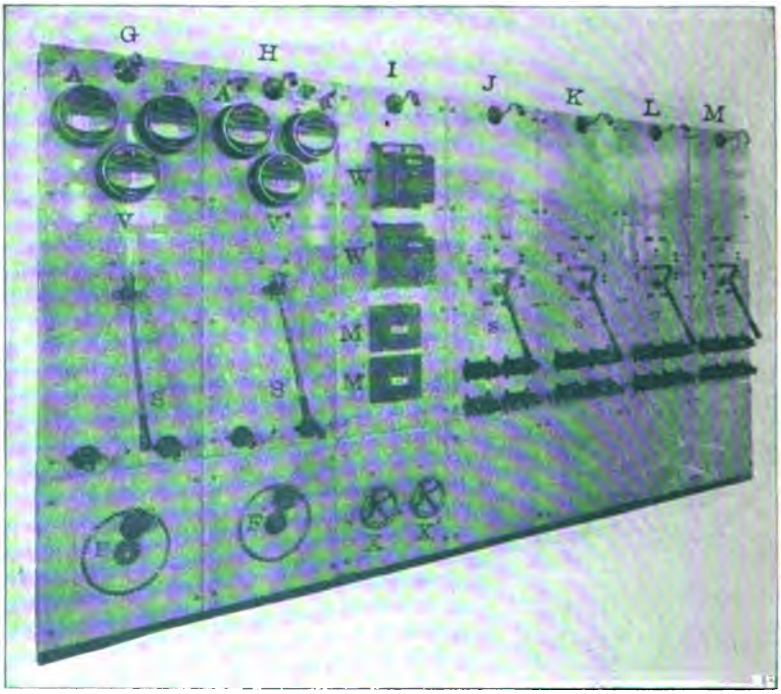


Fig. 176—" Westinghouse " Type " 6 " Switchboard.

Fig. 176, shows a Westinghouse Electric and Manufacturing Company's type " 6 " switchboard for two diphase generators delivering current to feeders at about 2,000 volts pressure. The first panel G, is a 300 K. W. generator panel.

A and a, are 100 ampere ammeters, one for each diphase armature circuit. v, is the voltmeter, which may be transferred to either circuit. S, is the main generator plunger switch-handle, the diphase connections being made and broken at the back of the board. F, is the generator field rheostat.

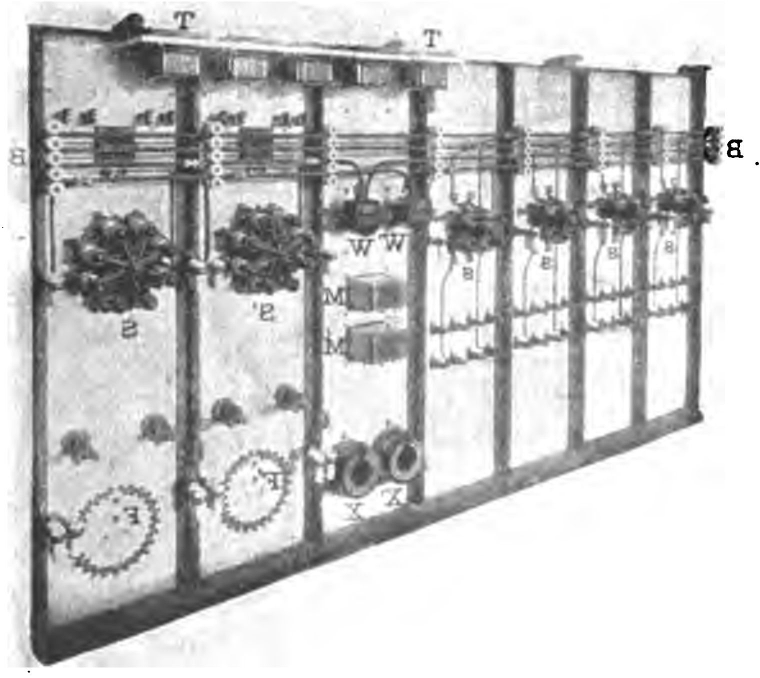


Fig. 177—Rear View of Switchboard Shown in Fig. 176.

Panel H, only differs from panel G, in the fact that the generator connected thereto has 500 K. W. capacity, and the instruments are correspondingly arranged.

On panel I, are two integrating wattmeters, W and W′, one for each diphase circuit. These record the total amount of electrical energy supplied by the generators jointly to each diphase circuit in watt-hours or kilowatt-hours. M, M′, are main-circuit ammeters, one for each diphase circuit, and indicating the total current supplied by both generators to these circuits.

Panels J, K, L, M, are feeder panels carrying diphase switches s, s, s, s.

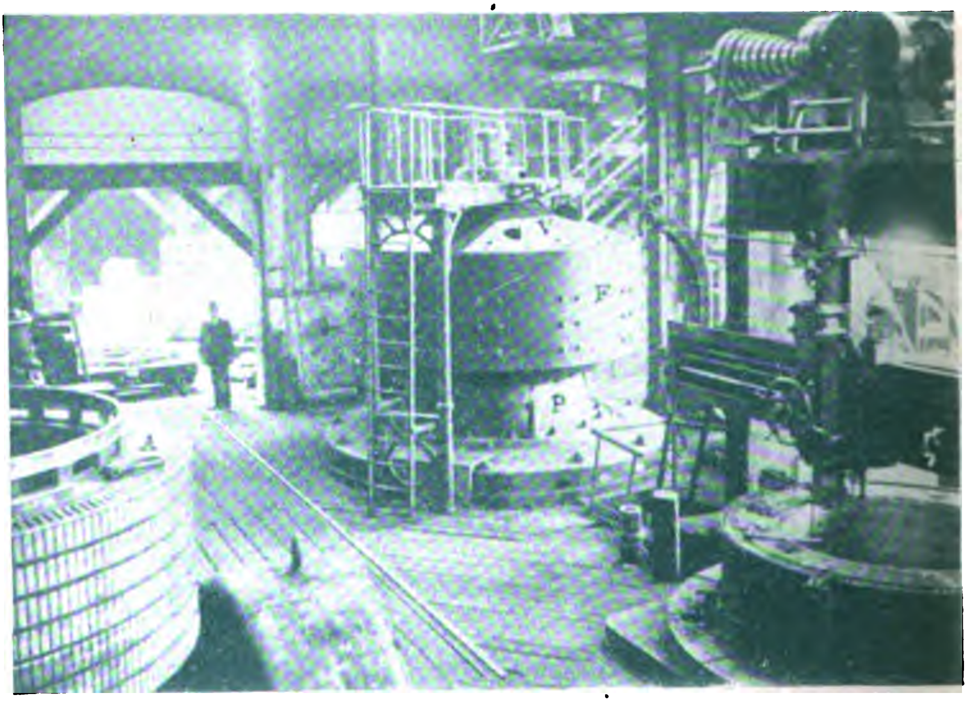


Fig. 178—5000-H. P. Two-Phase Generator at Westinghouse Factory.

The back of this board is shown in Fig. 177. It is only partly wired. S, S′, are the main switches. F, F′, show a circle of clips to which are soldered wires running to separate field rheostats. In other words, the field-rheostat boxes, being somewhat too large to fasten directly to the back of the switchboard, are placed in a separate structure and connected

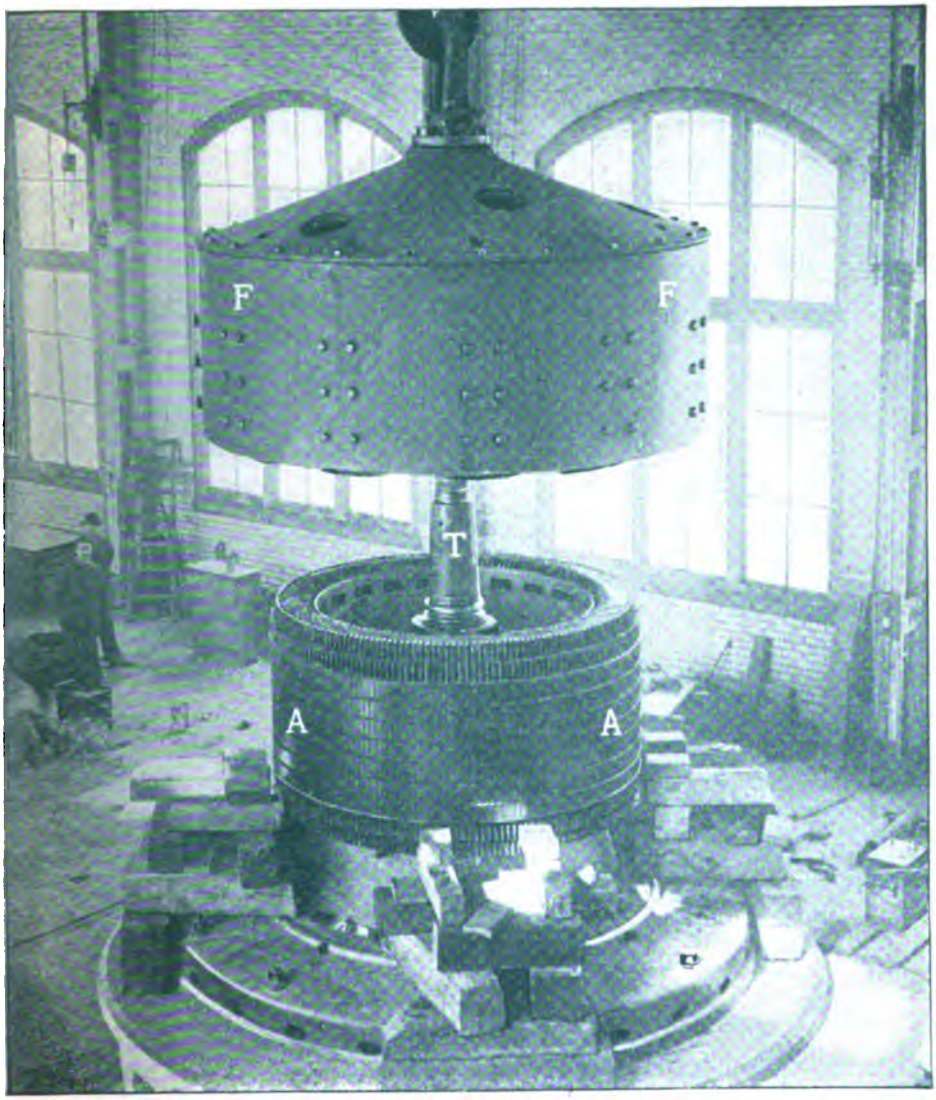


Fig. 179—"Westinghouse" Electric 5000-H. P. Niagara Falls Generator.

by a number of wires to the contacts on the switchboard face. X, X′, are the exciter rheostats. B, B, are the four diphase bus-bars which are supplied by the generators through the switches S, and which supply the various feeders through the switches *s*. T, T, are transformers for operating the voltmeters at a reduced pressure.

Fig. 178, shows the Westinghouse Electric Company's first five-thousand horse-power diphase generator, employed in the power-transmission system of the Cataract Construction Company, for the distribution of power from Niagara Falls. P, is the cast iron pedestal which supports the stator armature.

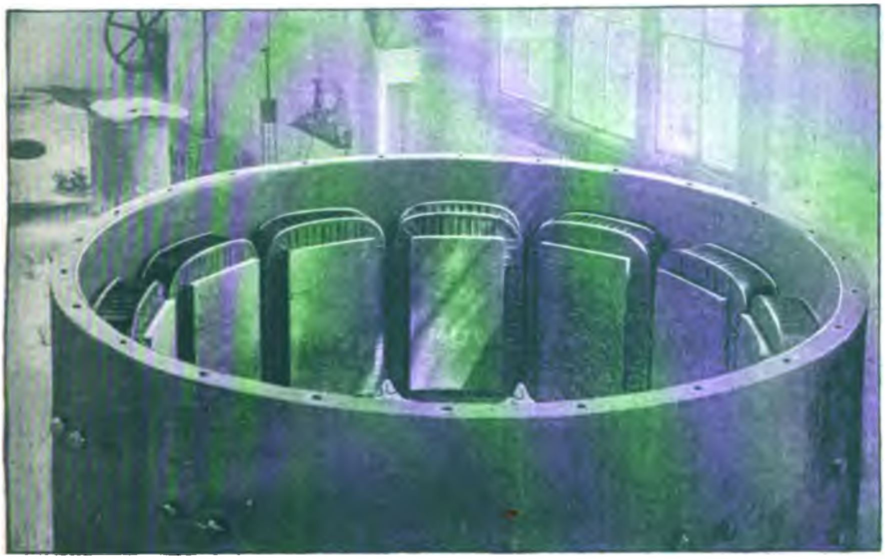


Fig. 180—Westinghouse Electric Field-Ring with Poles and Bobbins in Place for Niagara Falls Two-Phase Generator.

F, is the external rotor field frame which is of the umbrella type. V, is a ventilator placed in the field cover, for forcing air through the machine when in operation. r, is a pair of collector rings for supplying continuous current to the revolving field. A detached armature, for a machine of the same size, is shown at A.

The construction of the machine is readily seen from an inspection of Fig. 179, which represents the first generator in process of installation at the Niagara Power House. T, is the vertical turbine shaft, which carries the rotary field. AA,

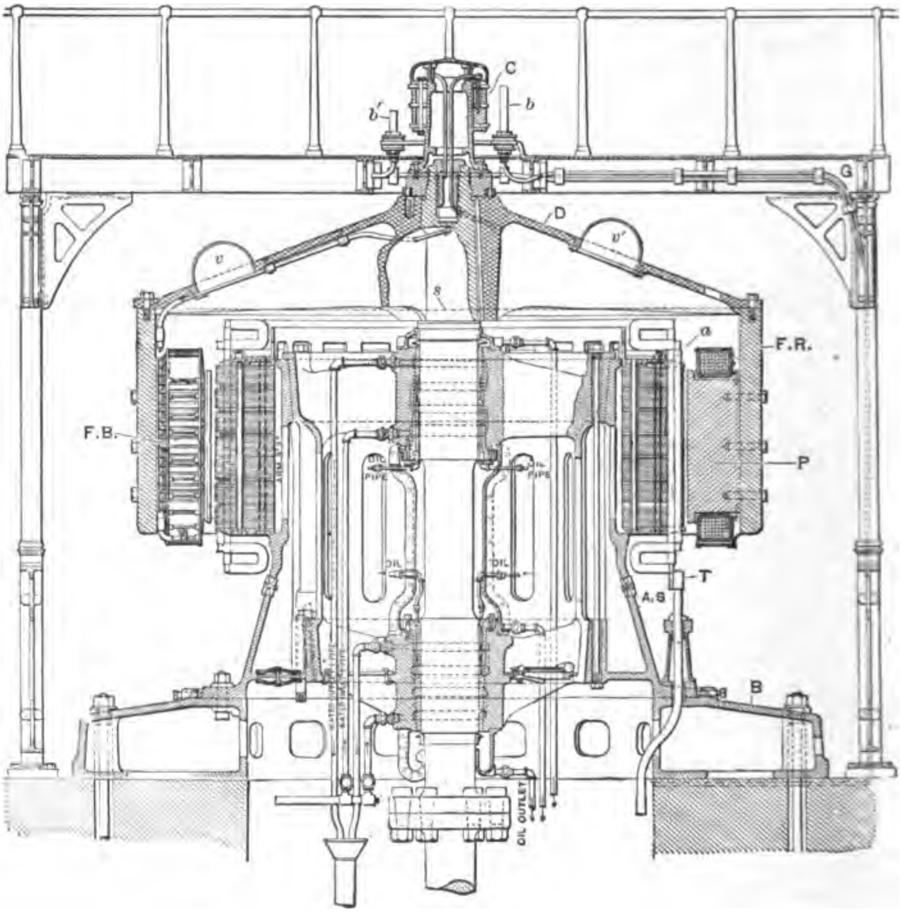


Fig. 181—Vertical Section of one of the 5000-H. P. "Westinghouse" Niagara Generators.

is the stator armature, and FF, the rotor field, suspended over its shaft. The interior of the revolving field-ring is shown in Fig. 180. Twelve field poles are here shown, bolted in position around the periphery of the ring. Each field pole carries a massive exciting coil.

Fig. 181, shows a vertical cross-section, and Fig. 182, a horizontal cross-section, of one of these generators. These

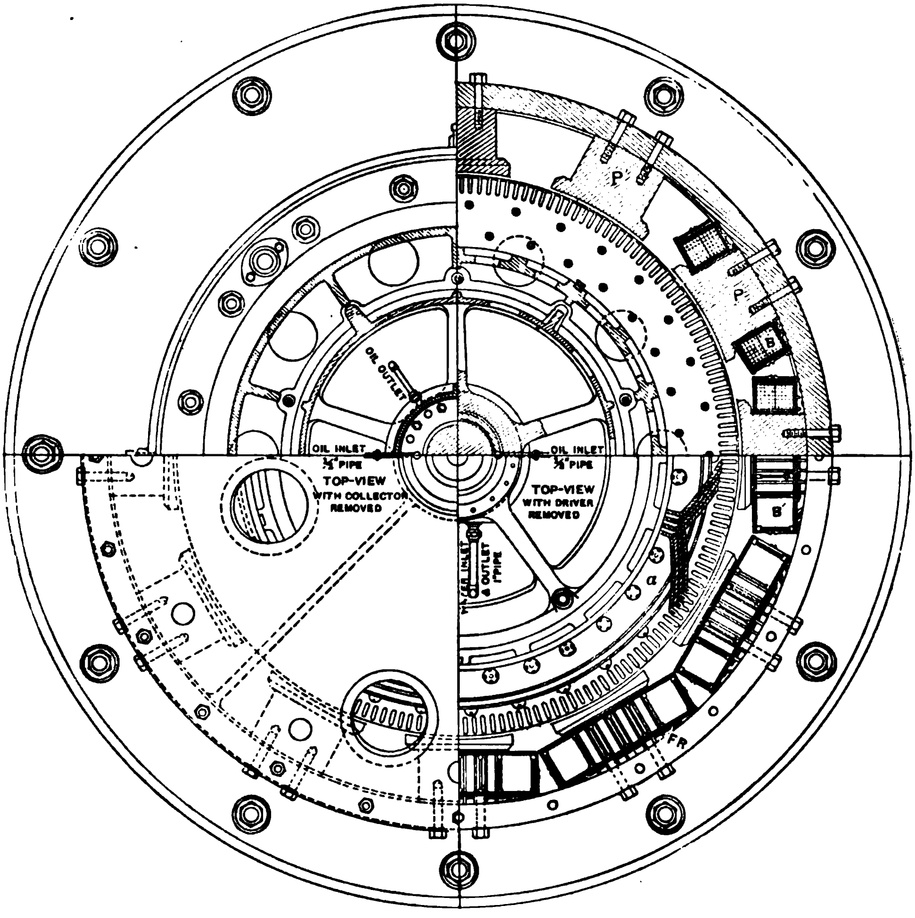


Fig. 182—Horizontal Section of one of the 5000-H. P. "Westinghouse" Niagara Generators.

machines weigh 170,000 pounds each, of which 79,000 pounds are in the rotor, and the remainder in the stator. Each generator is 11 feet 6 inches high, to the top of the bridge floor; the external diameter is 11 feet, 7⅛ inches. The speed of rotation is 250 revolutions per minute. Consequently, the frequency of alternation is 3,000 alternations per minute, or 25 cycles per second. The armature is wound with two separate diphase circuits, in each of which the pressure is, approximately, 2,000 volts. The field is excited by a continuous current, at a maximum of 150 volts, and consumes less than 15 horse-power.

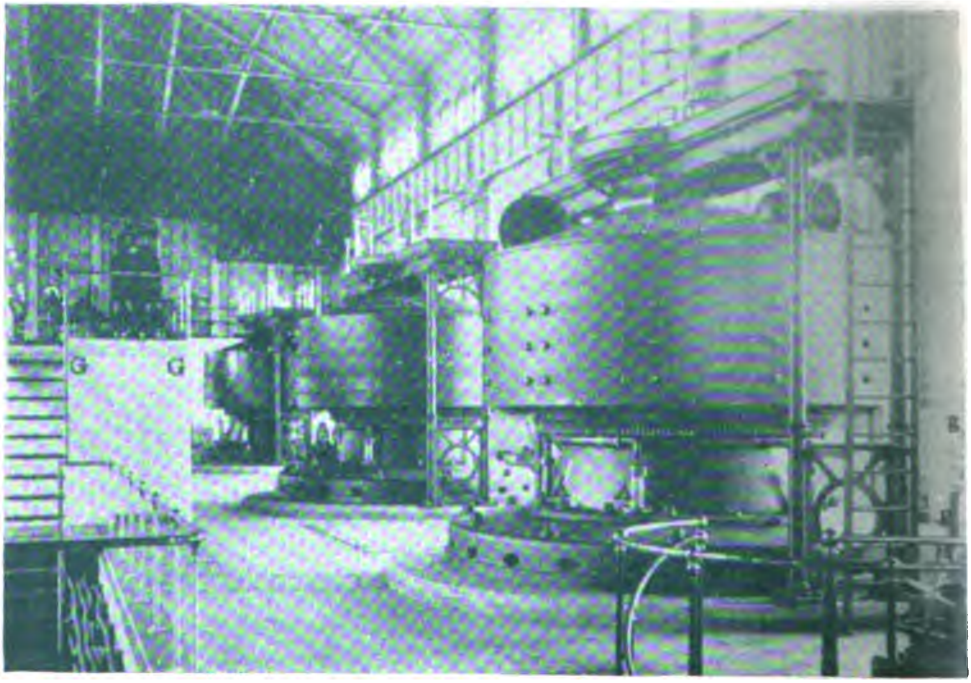


Fig. 183—" Westinghouse " 5000-H. P. 2-Phase Generators at Niagara Falls.

Fig. 183, shows three Westinghouse diphase 5,000 H. P. generators, installed in the power-house at Echota. No. 2 was running at the time the photograph was taken. G G, is the switchboard gallery. A, A, are two of the four pedestals receiving the armature terminals. *g g*, is a turbine governor.

Fig. 184, shows a general view of the Echota Power House of the Cataract Construction Company, with three Westinghouse 5,000 H. P. generators installed. T, T, are rotary transformers for supplying a continuous current to the revolving field magnets of the generators. S, is the generator switchboard. s, is the rotary-transformer and field-magnet switchboard. At S, each generator has a separate switchboard, with two sets of instruments, one for each of the diphase armature circuits. The instruments in the top row are ammeters; those in the second row, voltmeters;

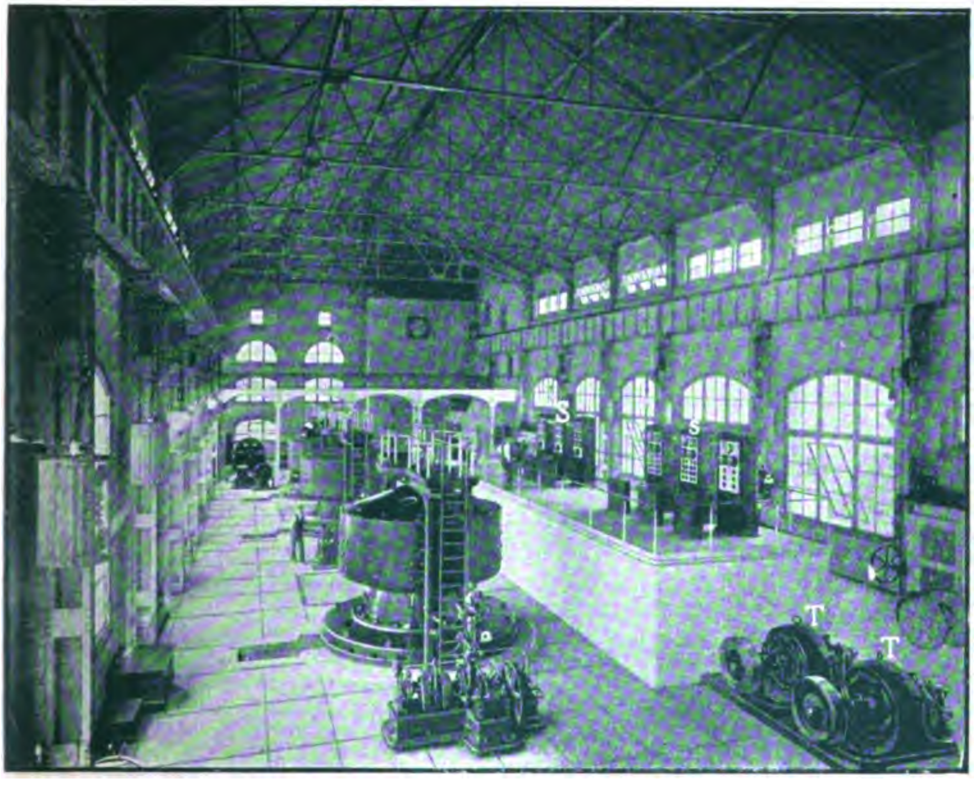


Fig. 184—"Westinghouse" 5000-H. P. 2-Phase Generators at Niagara Falls.

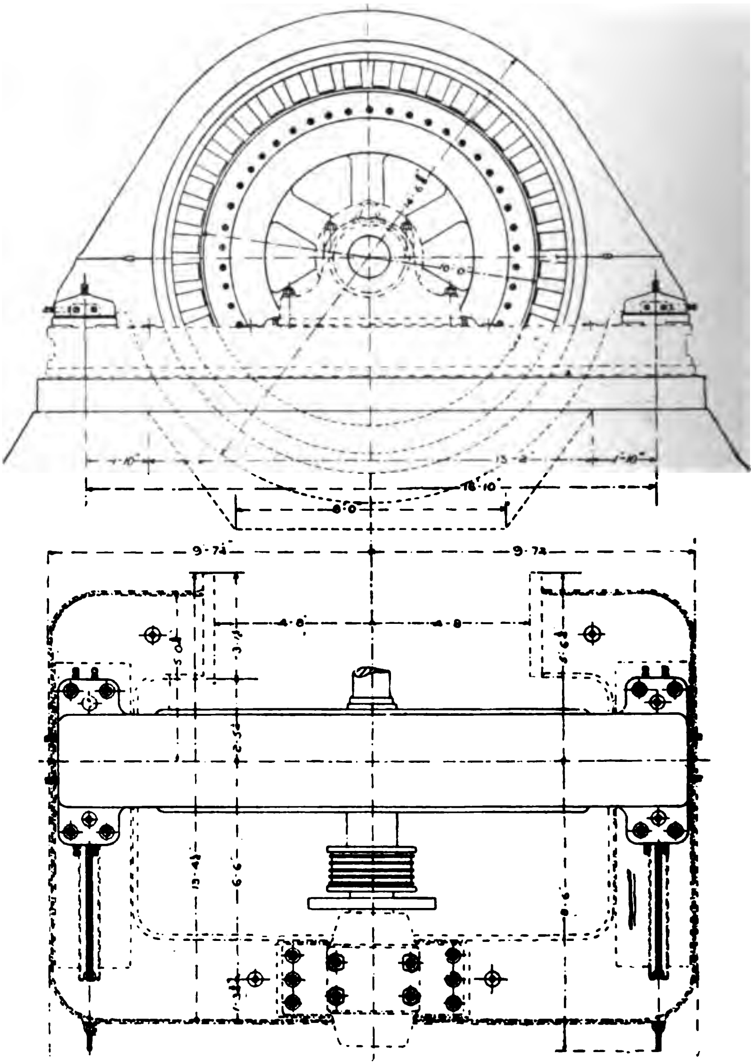


Fig. 188—End Elevation and Plan of "Westinghouse" 1200-K. W. Direct Connected Two-Phase Generator.

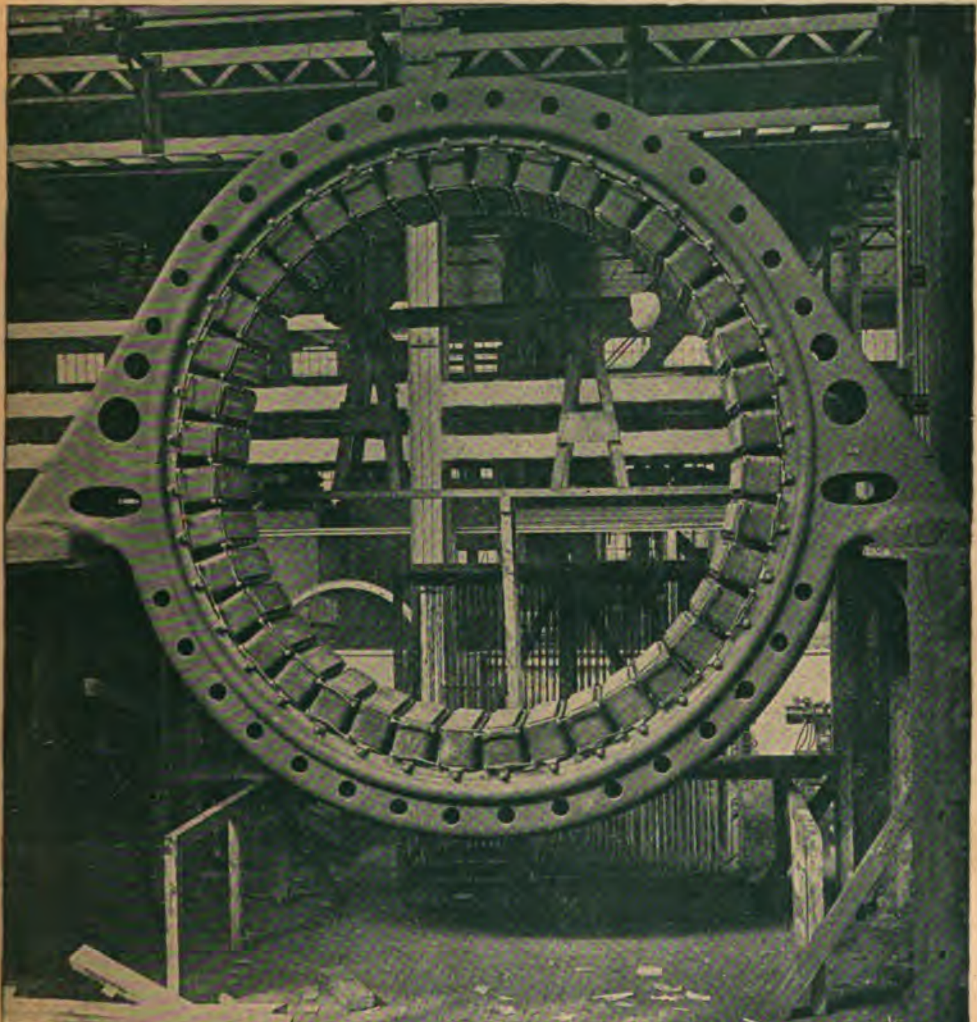


Fig. 185—Field Frame of Westinghouse 1200-K. W. Direct-Connected Two-Phase Generator.

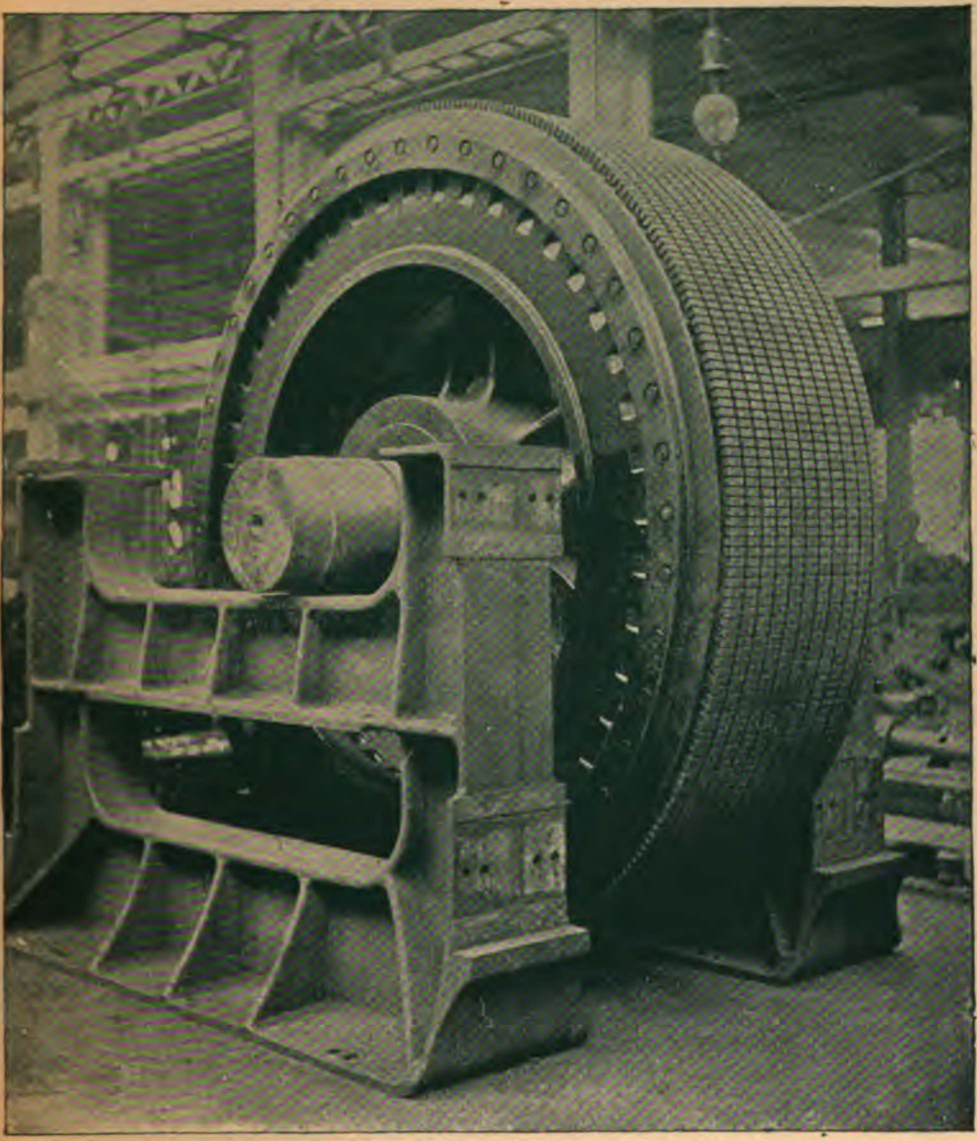


Fig. 186—Armature of "Westinghouse" 1200-K. W. Direct-Connected Two-Phase Generator.

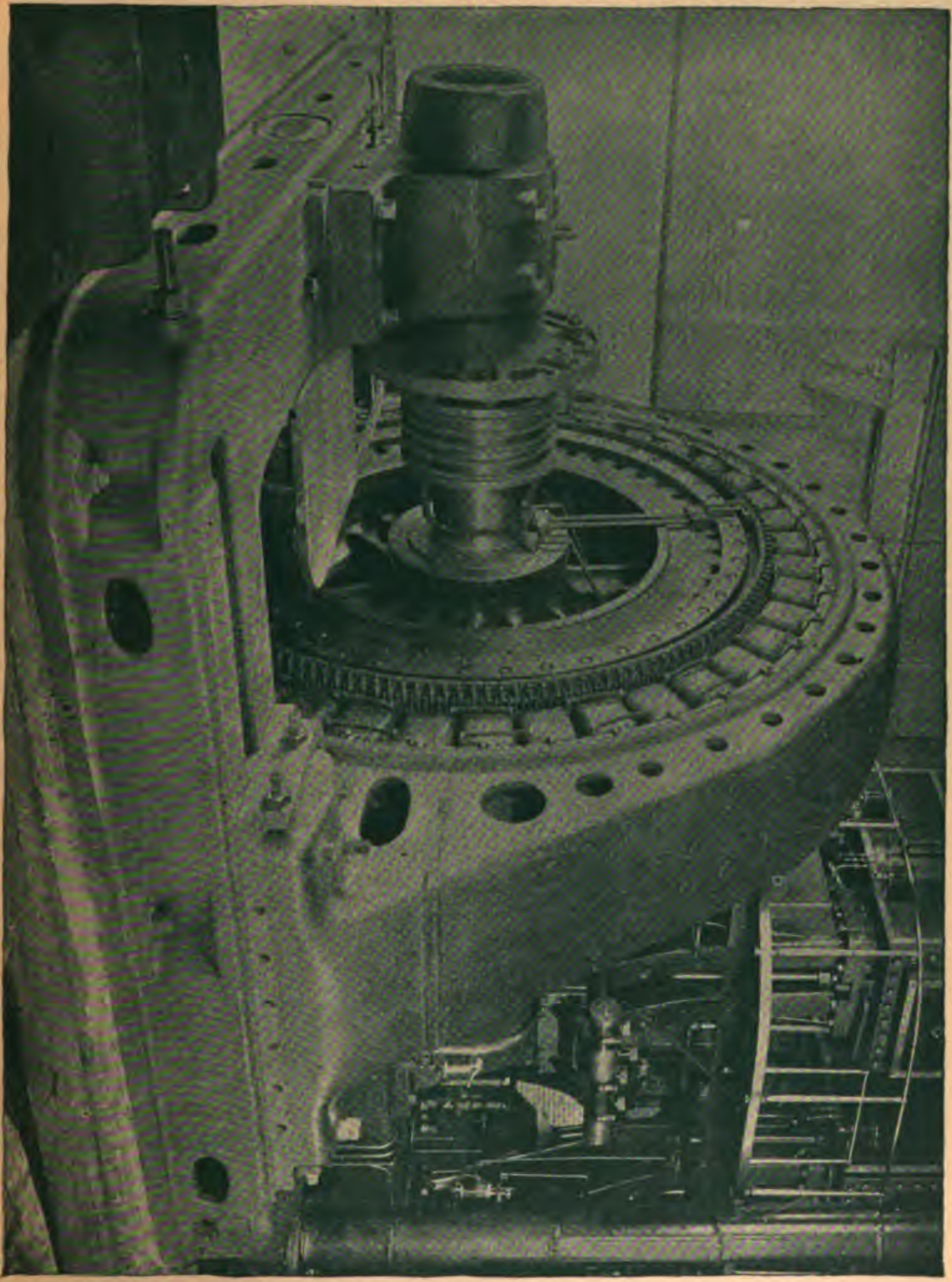


Fig. 187—"Westinghouse" Direct-Driven 1200-K. W. Two-Phase Generator.

the third row, wattmeters; and on the fourth row is a single continuous-current ammeter in the field circuit. There are also phase indicators for connecting the machines in parallel. All the instruments are operated through transformers, so that they are not in metallic connection with the 2,000-volt generator pressure. The main switches are situated immediately below the gallery, and are operated by compressed air under control from the gallery.

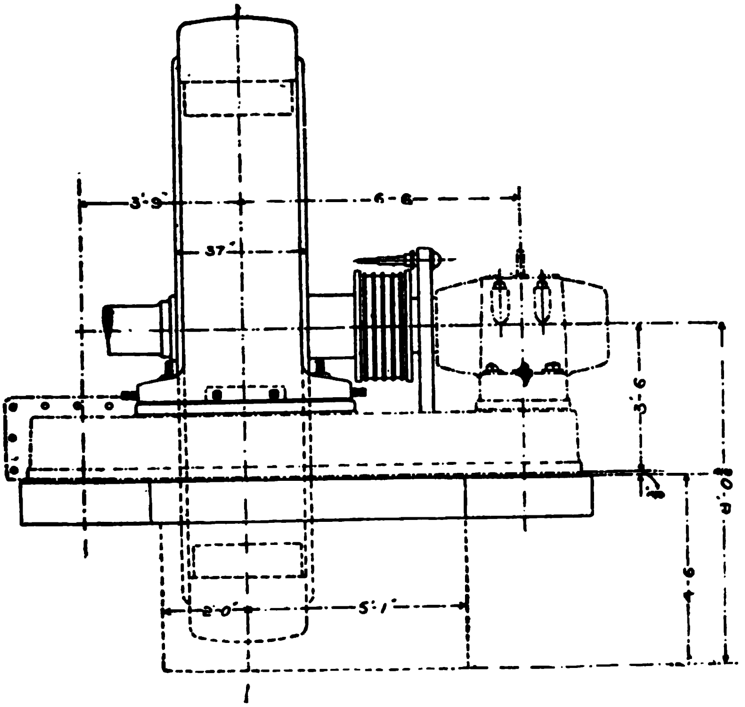


Fig. 189—Side Elevation of "Westinghouse" 1200-K. W. Direct-Connected Two-Phase Generators.

Figs. 185, 186 and 187, show the field, armature and assembled machine, of one of the Westinghouse Company's diphase direct-driven generators, as built for the Missouri Electric Light and Power Company, Saint Louis, Mo. This machine gives 1,200 K. W., at 1,200 volts pressure, and runs at 180 revolutions per minute. It has 40 poles, consequently, the frequency of alternation is 7,200 alternations per minute, or 60 cycles per second. It is directly connected to a triple-expansion compound-engine, of the Lake Erie Engineering Company. Each pole-piece is made up of 1,600 soft steel plates, clamped side by side, and cast into the field frame. The armature, which is 10 feet in diameter, is of the regular iron-clad type, with ventilated spaces, and forms the fly-wheel of the engine. The dimensions of this machine are given in Figs. 188 and 189.

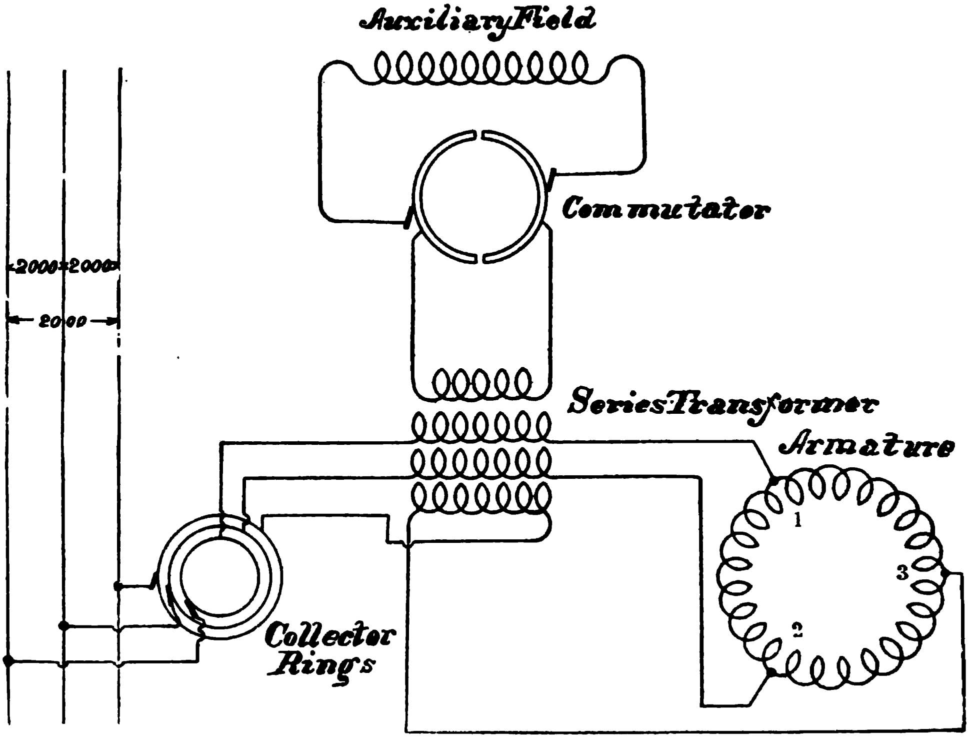


Fig. 190—Diagram of Connections for "Westinghouse" Three-Phase Generators.

The Westinghouse diphasers of the type represented in Fig. 145, are also wound as triphasers. In this case there are three collector rings on the shaft instead of four. The armature is tapped at three equidistant points, 120° apart, instead of in four, 90° apart, as in diphasers, and one collector ring is connected to each of the three taps. The connections of a composite field, or compound-wound triphaser with the external circuit, are represented in Fig. 190. Here, the armature is tapped at the points 1, 2 and 3, which are connected to their respective collector rings through the primary coils of a small series transformer, wound on the internal spokes of the armature. The secondary coil of this transformer, excited by the main line currents, is connected to the auxiliary field winding, through the commutator, as shown. Each collector ring is connected by its brush with one of the external conductors.

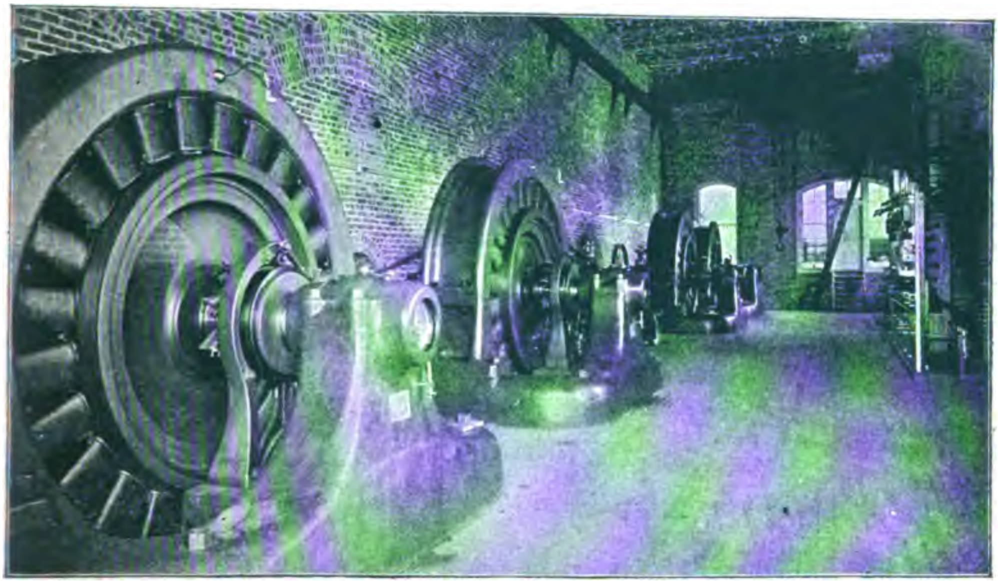


Fig. 191—Four "General Electric" 750-K. W. Direct-Driven Triphase Generators.

Fig. 191, shows four of the General Electric Company's 750 K. W. direct-driven triphase generators, installed at the Folsom generating station of the Sacramento Electric Power and

Light Company. These are 24-pole machines, running at 300 revolutions per minute, and, therefore, having a frequency of 60 cycles per second. They generate a pressure of 800 volts, which is raised to 11,000 volts by step-up transformers for transmission to Sacramento, a distance of 24 miles. These machines are so wound that when a full non-inductive load is thrown off, the pressure only rises 6 p. c., at the terminals. The machines are direct-connected to horizontal turbine shafts. They have three collector rings, and a commutator for compounding. The switchboard for controlling these four machines is shown on the right-hand side of the figure.

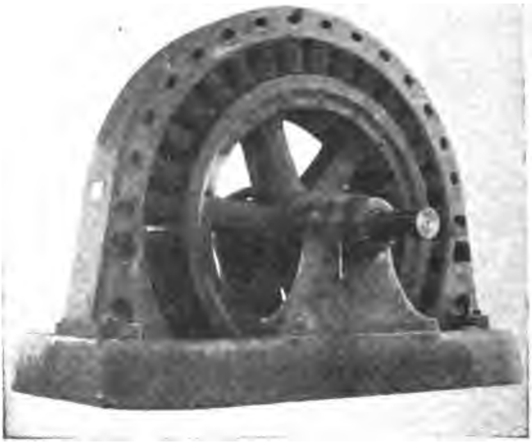


Fig. 192—"General Electric" Three-Phase Generator, 750-K. W.

A General Electric Company's three-phase generator of 750 K. W., installed at Columbia, S. C., is represented in Fig. 192. This machine has 32 poles, and runs at 150 revolutions per minute, so that its frequency is 40 cycles per second. It has laminated field poles, cast into the field frame, and develops a pressure of 3,450 volts in each circuit.

A General Electric Company's three-phase generator constructed for the Lachine Rapids Land and Improvement Company, supplies light and power a distance of 6.1 miles to Montreal. This machine is shown in Fig. 192 A. It has 40 poles, and runs at 175 revolutions per minute, or has a frequency of 58.3 cycles per second. It delivers 750 K.W. or

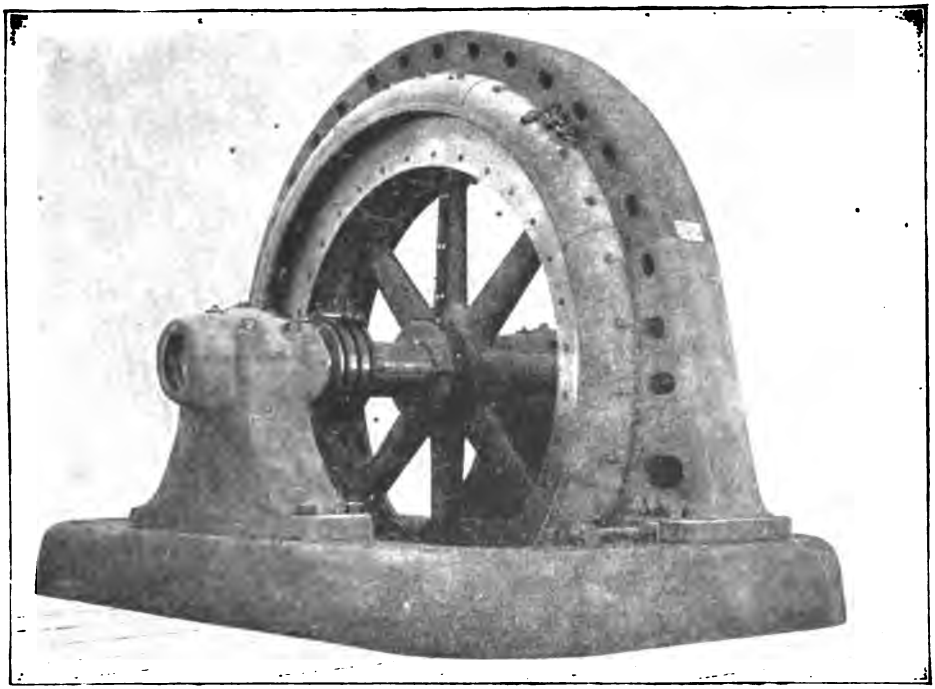


Fig. 192 A—" General Electric " 750 K. W. Three-Phase Generator.

1,000 H.P., at a pressure of 4,400 volts in each circuit. The field is, in this case, the rotor, and the armature is the stator. Each pole of the revolving field is bolted to a forged steel ring, forged without a weld. The field coils are formed of rectangular ribbon, or strip copper, wound on edge. The collector rings are of cast iron with carbon brushes. The stationary armature may be slid sidewise for convenience of inspection, cleaning, or repairs to either armature or field. It also has the usual screw bolts for adjustment in a vertical direction, thus permitting the movement of the armature so as to keep it at all times concentric with the revolving field and regulating the bearing wear.

Fig. 193, shows three General Electric Company's triphasers, and two continuous-current machines, installed at the generating station of the Portland General Electric Company, Portland, Oregon. The three-phase generators have twenty poles and generate 450 K.W. at a pressure of 6,000 volts in each circuit. They run at 200 revolutions per minute and, therefore, have a frequency of 33 cycles per second. They are mounted directly on the vertical shafts of turbine wheels. Three collector rings of each machine are visible above the platforms. The continuous-current machines are six pole, 280 K.W. generators delivering 650 volts at 125 revolutions per minute, and are also mounted on vertical turbine shafts. The three-phase generators transmit power by triphase alternating currents on three conductors to step-down transformers at Portland, a distance of fourteen and one-half miles, where a rotary converter of a type to be subsequently described, converts the alternating currents into a continuous current, which is delivered to a street railway at 500 volts pressure. This plant, which was installed in May, 1895, was, probably, the first instance of the operation of a street railroad by triphase currents through a rotary transformer, at a considerable distance from the generator. The street-railway system at Buffalo, N. Y., is at the present time operated in part by Niagara power, transmitted a distance of some twenty miles.

The connections of a General Electric Company's composite-field, or compound-wound three-phase generator are shown in Fig. 194. The main excitation is supplied by a separate

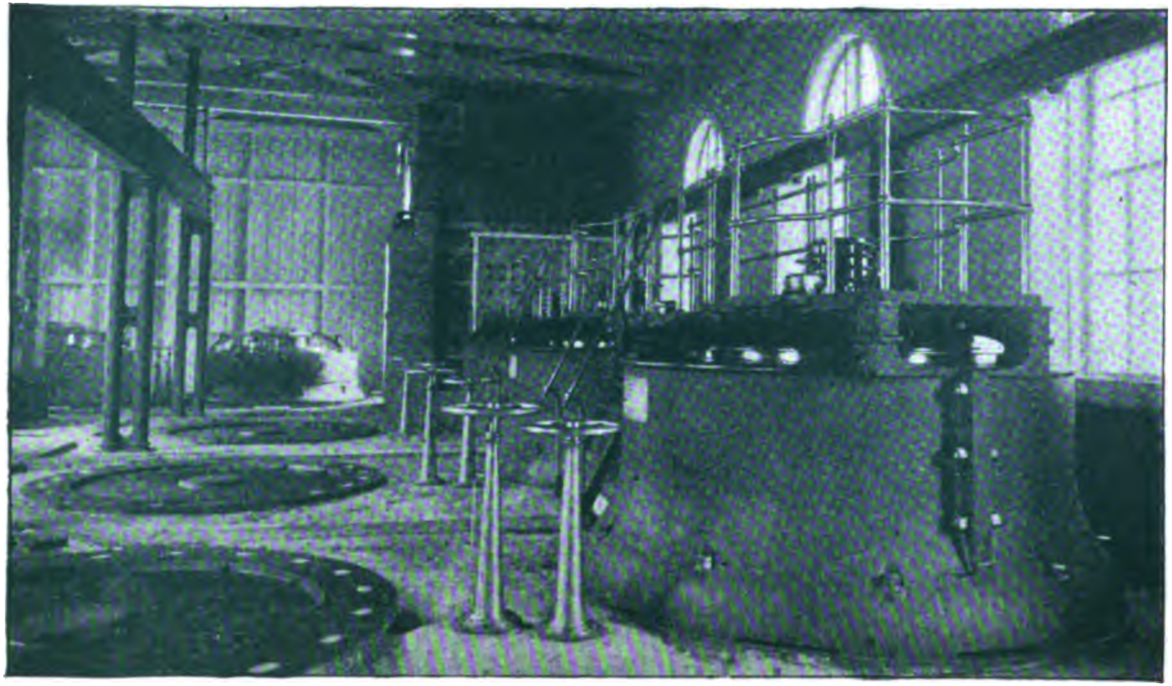


Fig. 193—Three General Electric Three-Phase Generators and Two Continuous-Current Machines.

exciter of the usual continuous-current type. The compound excitation is supplied by commuting a portion of the main

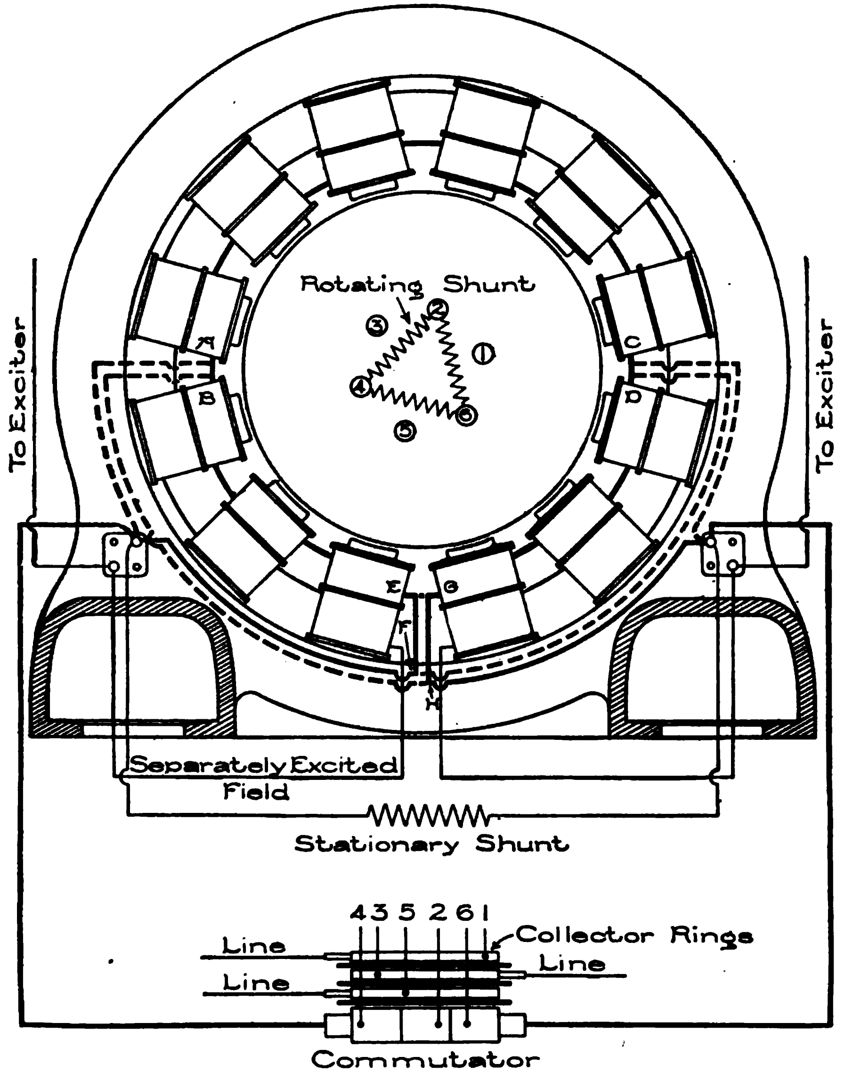


Fig 194.—Connections for Series Field of "General Electric" Three-Phase Generator.

armature current. This is accomplished by connecting the three terminals 2, 4 and 6, of the rotating armature with the successive bars of the commutator. The brushes rest on this commutator, and carry the commuted current to the auxiliary field-winding, which is shunted by a stationary shunt as shown. The three triphase armature windings are taken from the triangular rotating shunt as a centre and terminate at the points 1, 3 and 5, which are connected directly to the main collector rings. The auxiliary excitation is, therefore, taken from the centre of the armature winding. The degree of compounding required may be varied by adjusting the external stationary shunt.

Where two or more three-phase generators are installed in a station, it is often important to be able to operate them in parallel, that is to say, connect them together so that they all deliver their currents simultaneously through a set of bus-bars into the same circuit, like incandescent-lighting continuous-current generators, or railway generators. With continuous-current generators, it is a comparatively simple matter to connect them in parallel, since it is only necessary to connect all the positive terminals together to the positive bus-bar and all the negative terminals to the negative bus-bar, taking care that the pressure at the terminals of each new machine introduced shall be practically the same as the bus-bar pressure; since otherwise, a powerful current would be thrown upon the new machine at the instant of closing its switch. With alternators running in parallel it is, besides this, necessary that they shall be practically in step at the moment of closing their switch, and this is a more important consideration than the equality of their pressure. If they are not in step at the moment of throwing them on the circuit, a powerful current is sent through the armature tending to bring it into step, and this may either blow the fuses or injure the machine. With multiphasers, it is also important that they should be thrown into step phase with phase. The switchboard connections suitable for throwing two of the General Electric Company's three-phase generators together, in parallel, are shown in Fig. 195. A_1, ,A_2, are the two armatures, the fields of which are partly separately excited and partly compound excited, the amount of the com-

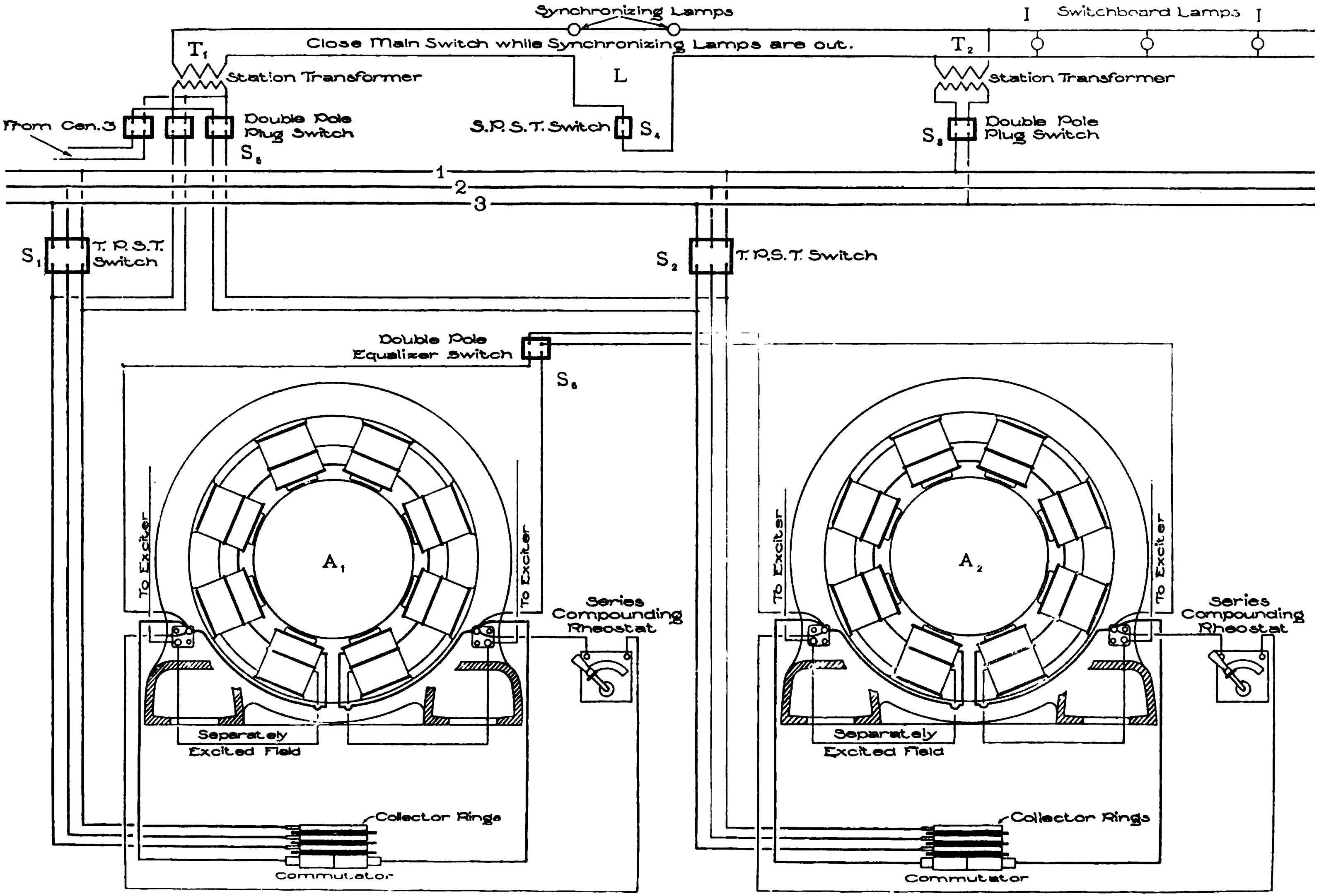


Fig. 195.—Connections for throwing two "General Electric" Triphasers (Composite Field) together at a Switch

pounding being controlled by the series compounding rheostats, on the right-hand side of each machine in the diagram, forming a stationary shunt. Let us suppose that the machine A_1, is connected with the external circuit wires or bus-bars 1, 2, 3, by the switch S_1. If now the load increases so that it is necessary to operate the machine A_2, this is first run up to speed and excited to standard pressure by its exciter. The double-plug switch S_3, is then closed, connecting the primary of the stationary transformer T_2, with the bus-bars through the secondary coil. This causes the synchronizing lamps L, to light up as soon as the secondary circuit is closed through the single-pole switch S_4. The primary of the other station transformer T_1, is then excited from the right-hand double-plug switch S_5, which connects it with the outside terminals of the armature A_2. There are thus two generators at work in opposition to each other upon the synchronizing lamp L. T_1, being operated by the new machine S_2, and T_2, being operated from the bus-bars, and, therefore, by the working machine. If the new machine is not exactly in step with the working machine, the lamps L, will glow, waxing and waning alternately with greater or less rapidity. The speed of the armature must be so controlled that the glowing and waning take place more and more slowly, until finally the lamps are extinguished for a decided period. The two machines are now in step and, therefore, completely oppose each other, as is shown by the disappearance of the secondary current and the extinction of the light. The switch S_2, of the new machine, is thrown at this instant, when the new machine will be coupled electrically with the original one and both will continue to operate in step. The double-pole equalizer switch S_6, should then be closed so as to throw the two field-windings in parallel and, therefore, equalize the compounding, so that any change in load shall have an equal influence on the two machines. After the machines have once been thrown in multiple, switches S_4 and S_5, may be opened, leaving S_3, closed to operate the switchboard lamps l, l, as pilot lights from the bus-bars.

Figs. 196 and 197, show with the accompanying table, the

Poles.	KW.	Speed.	Weight.	Fig.	A	B	C	D	E	F	G	H	I	J	K	L
8	50	900	5,750	120	68¾	26⅜	11	21	52¼	25	6	26½	14¾	....	51½	70
8	75	900	7,720	120	74⅝	29½	15	21	55¼	25	6	27¾	16½	.....	51½	70
8	100	900	8,950	120	82⅛	33	17	21	58¾	25	6	30	17¾	......	51½	70
12	150	600	14,800	120	97⅜	$41\frac{1}{16}$	.23	32	70⅝	31½	7	31⅛	19¼	......	62½	84
16	250	450	27,200	121	$143\frac{13}{16}$	54	38	42	132	24	9	38½	26	53½	60⅞	105
20	300	360	45,300	121	168	61½	44	53	156	28	9	43	28	67	67⅛	122

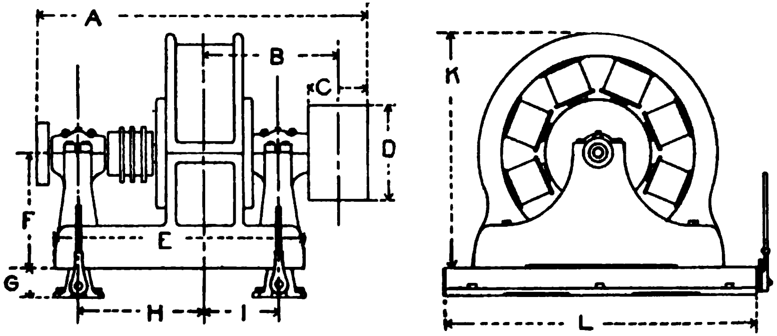


Fig. 196—Diagram of Dimensions of "General Electric" Multiphaser.

dimensions of the most common sizes of General Electric Company's triphasers. These are also wound as diphasers for diphase systems at the usual pressures.

Fig. 197 A, shews the circuit connections frequently employed with a triphase system. A, is the three-phase generator, operated by a Pelton water-wheel. The three collector rings of this generator are directly connected to the three lines wires, between any pair of which there may be, say, 2,000 volts; this pressure being determined by the armature winding, and being designed for the distance to which the power has to be transmitted. At D, is a three-phase rotary converter, which receives three-phase currents at, say, 380 volts pressure from the three step-down transformers, and converts them to continuous currents at, say, 550 volts pressure, delivered at its commutator brushes to the street railway system indicated. At F, is a series of incandescent lamps, such as might be employed in street lighting, and bridged across one pair of the high-pressure mains. At H, is an alternating current-arc lamp, operated at about 35 volts pressure by a separate step-down transformer. At C, is a three-phase induction motor, capable of

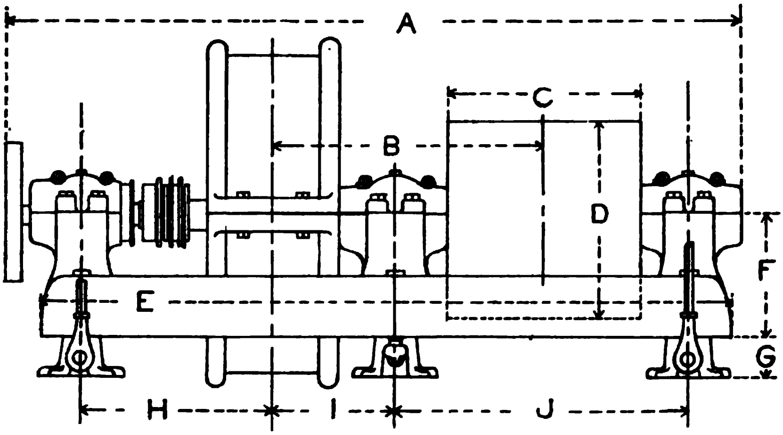


Fig. 197—Diagram of Dimensions of "General Electric" Belt-Driven Multiphase Generator.

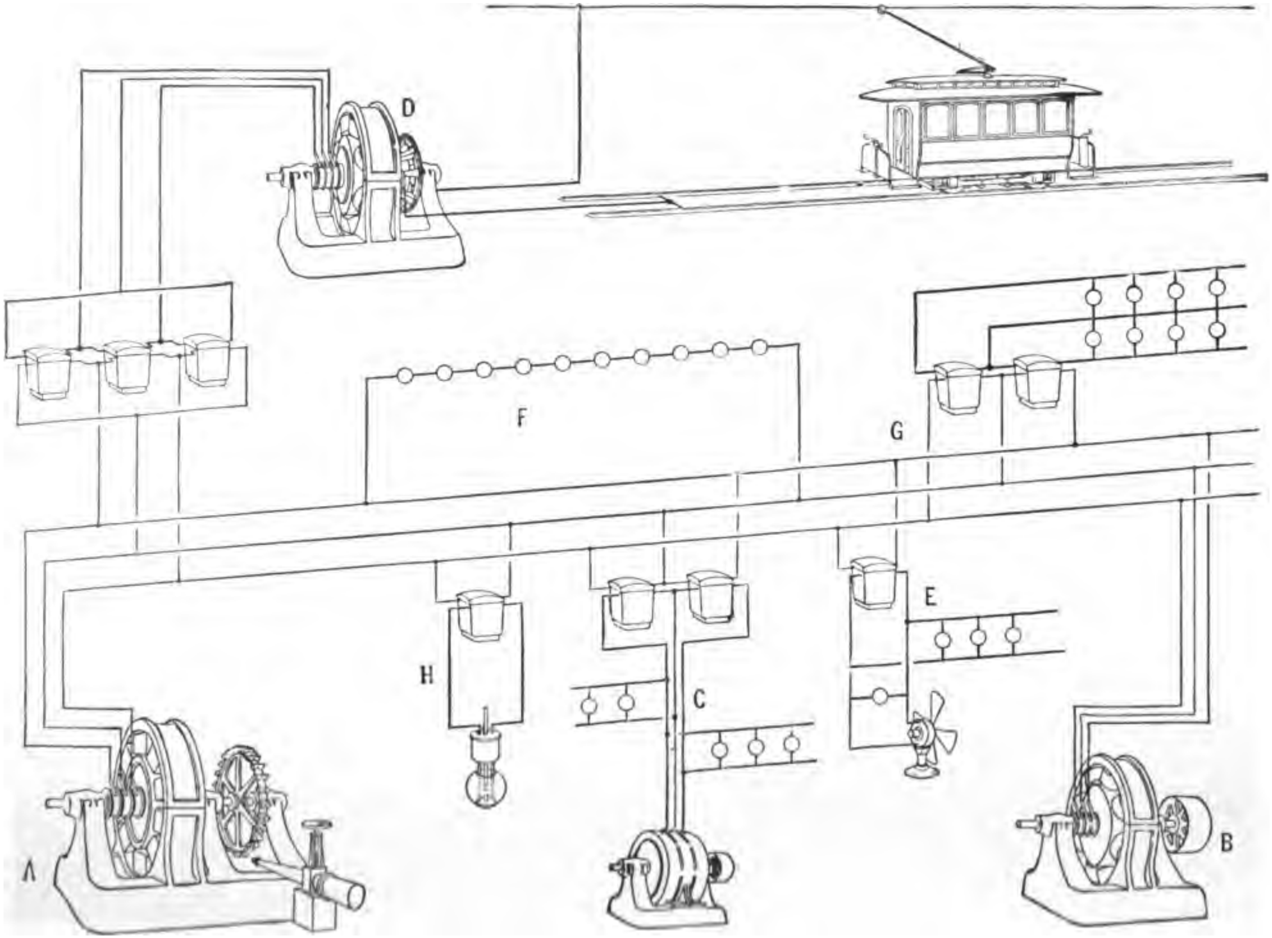


Fig. 107 A—Diagram of Three Phase Distribution System.

starting under full load, and operated at, say, 110 volts, with three-phase currents delivered from a pair of transformers, supplied by two sides of the high-pressure system. At G, is a three-wire incandescent lighting system, each side receiving say, 110 volts, and the currents in the two sides being in three-phase relationship to each other. At E, is a single-phase incandescent lighting and fan motor system supplied from one side of the high-pressure system. At B, is a synchronous three-phase motor, receiving the full pressure of the line, and capable of starting under light load.

The line connections of a triphase long-distance transmission system, are indicated diagrammatically in Fig. 198. A, is the three-phase generator driven by a Pelton water wheel. B, shows three transformers connected each with a primary between one pair of collector rings. The pressure is raised in these transformers, which are therefore called ***step-up transformers***, from say 2,000 volts to, say 11,000 volts. This is done in order to secure economy of copper, in transmission along the three triphase transmission lines, 1, 2 and 3. The transmission lines supply three sets of step-down transformers, C_1, C_2 and C_3, situated at different points. C_1, constitutes a ***sub-station***, where the pressure is reduced from 10,000 volts to, say, 2,000 volts, on the triphase distribution lines a, b and c. These supply a synchronous three-phase motor at M, without the intervention of transformers; induction motors as at m, through the intermediary of step-down transformers, with 115 volts in their secondary circuits, and groups of incandescent lamps, such as L′, L, and L, L_1, supplied on the two-wire or three-wire system at 115 volts, through step-down transformers.

The group of step-down transformers C_2, reduce the pressure directly to, say 120 volts, for local distribution to two induction motors such as F, incandescent lamps such as I and J, and arc lamps such as H. The pressure is regulated by the regulators G. The group of step-down transformers C_3, reduce the pressure to a suitable amount for supplying the rotary transformer D, from which a continuous current is

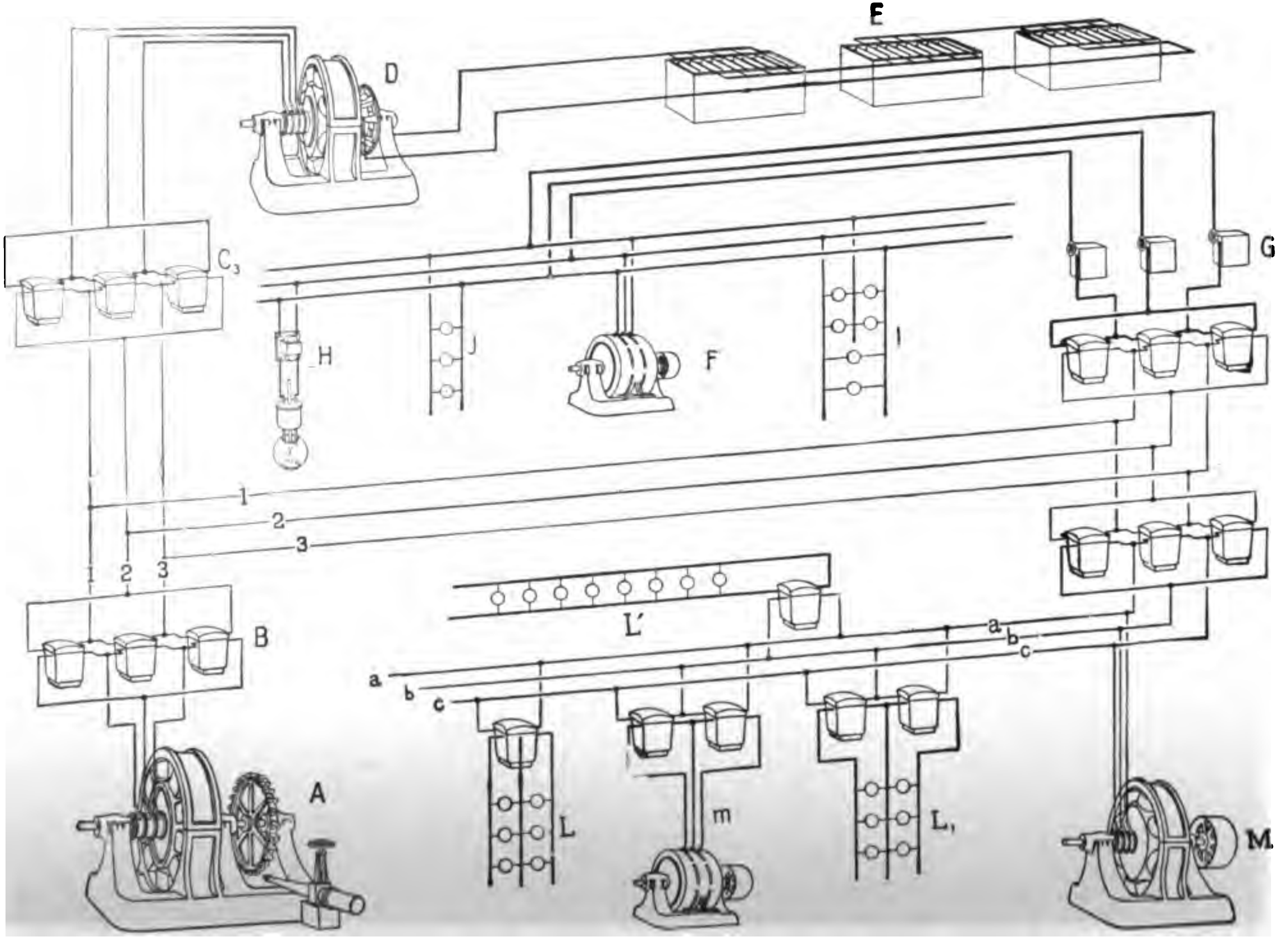


Fig. 108—Long-Distance Power Transmission with Step-up and Step-down Transformers.

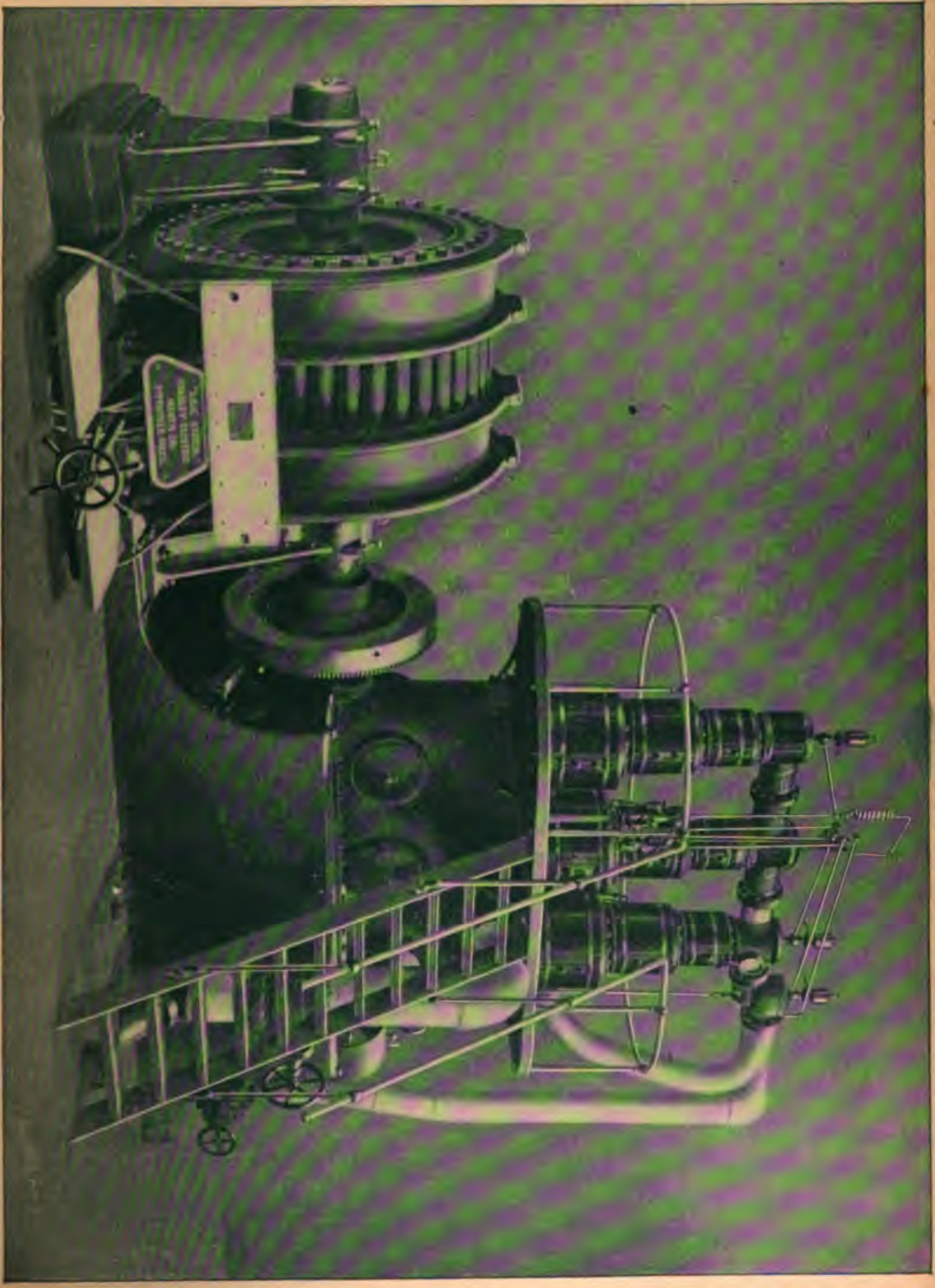


Fig. 190—A 300-K. W., S. K. C. Di-Phase Generator, Directly Connected to a Willans Engine.

delivered either to storage batteries, or electrolytic tanks E, or for street railway work.

Fig. 199, shows a 300-K.W. direct-driven Stanley-Kelly Company diphaser of the Stanley Electric Manufacturing Company. Here, the field-magnet core is the rotor, and the armature is the stator. These machines are usually constructed for a frequency of either 16,000 alternations per minute (133 cycles

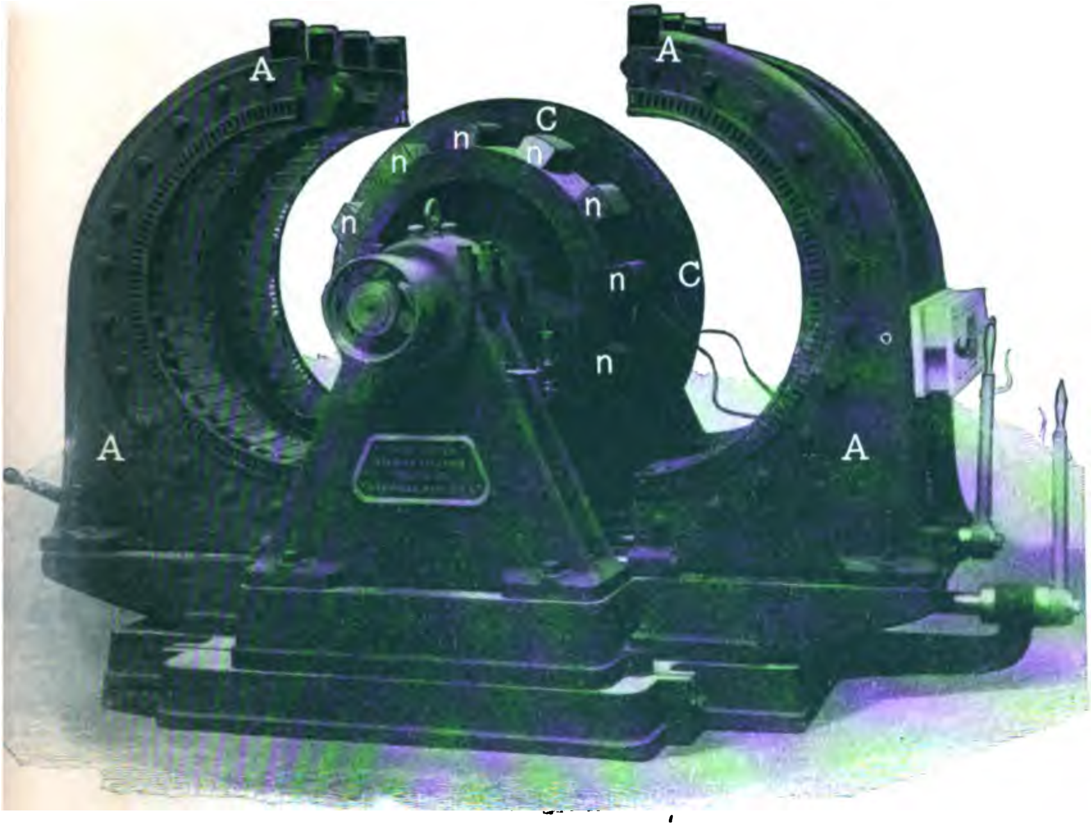


Fig. 200—180-K. W., S. K. C. Generator with Armature Drawn Apart. Side View.

per second), or 8,000 alternations per minute (66·7 cycles per second). They are usually wound in such a manner that they may be connected up together, either for 1,000 volts or for 2,000 volts in each diphase circuit. In large sizes they are wound up to 10,000 volts as required. The machine shown in Fig. 199, is directly connected to a Willans engine.

Figs. 200 and 201, show a 180-K. W. Stanley-Kelly Company's diphaser, with the armature frame open and closed. AA, is the stator armature ring wound with coils situated in grooves in a laminated iron core. n, n, n, are the projecting pole-pieces of the revolving field-magnet core, excited by the stationary field coil C, C, which receives its current through the wires shown P, is the main pulley; p, the exciter pulley; L_1, the belt-tightening lever; and L_2, the armature opening lever.

Some of the dimensions of the Stanley belt-driven two-phase alternators are given in the accompanying table.

DIMENSIONS OF STANDARD BELT-DRIVEN TWO-PHASE ALTERNATING-CURRENT GENERATORS.

KILOWATTS.	H.-P.	SPEED. Revolutions per Minute.	PULLEY.	
			Diameter Inches.	Face Inches.
40	53	1333	14	10
50	66	1333	14	10
60	80	1000	20	12
75	100	1000	20	12
120	160	800	24	18
135	180	800	24	18
150	200	800	24	18
180	240	666	28	22
240	320	400	48	36
300	400	400	50	38
400	533	333	58	48
500	666	286	72	51
600	800	286	72	51

Fig. 202, shows the rotor of one of these generators, provided with 8 polar projections at each end. These projections consist of sheets of iron of the proper shape, assembled and clamped together on a steel cylinder. All the

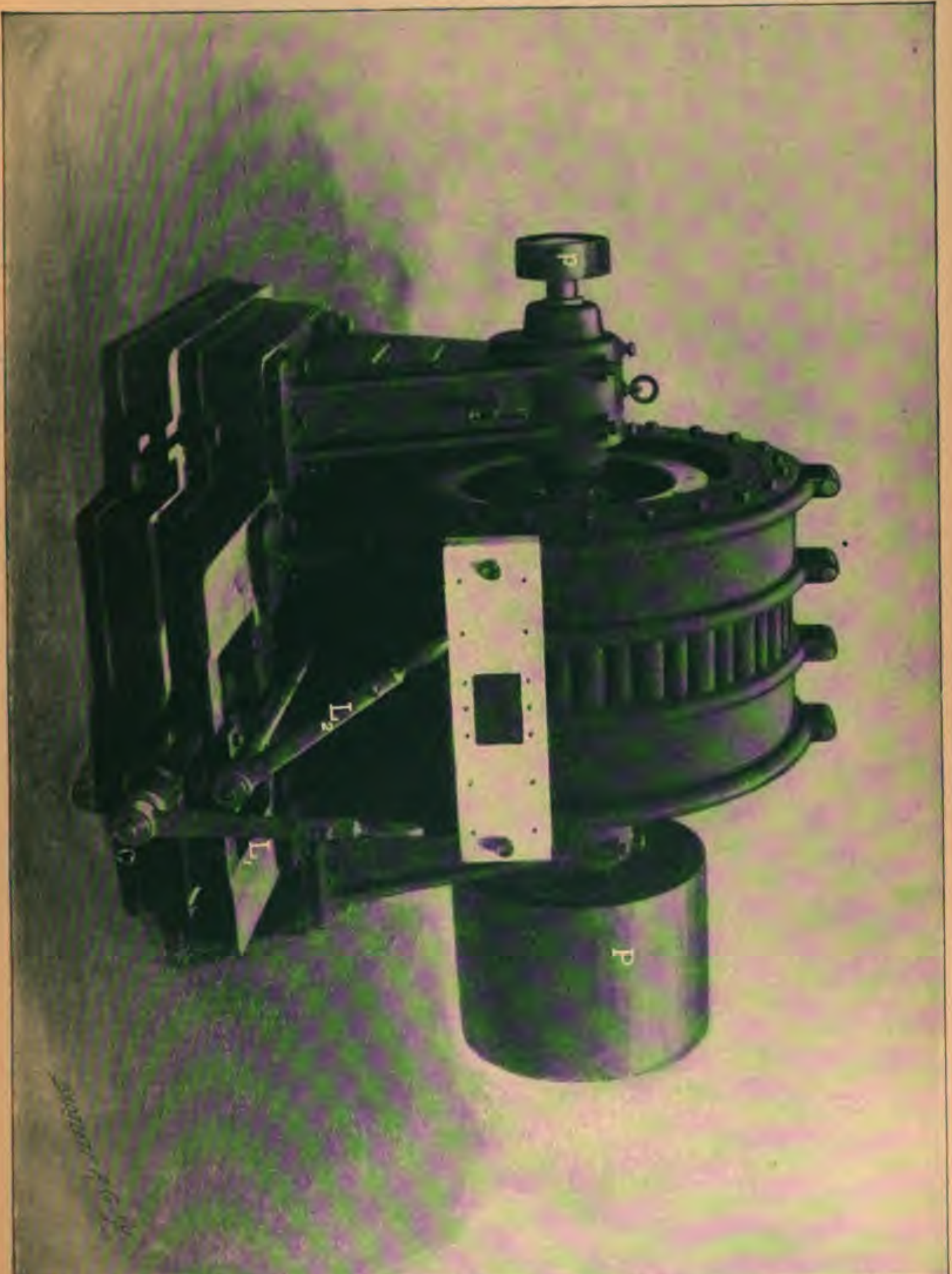


Fig. 201—180-K. W., S. K. C. Generator. End View.

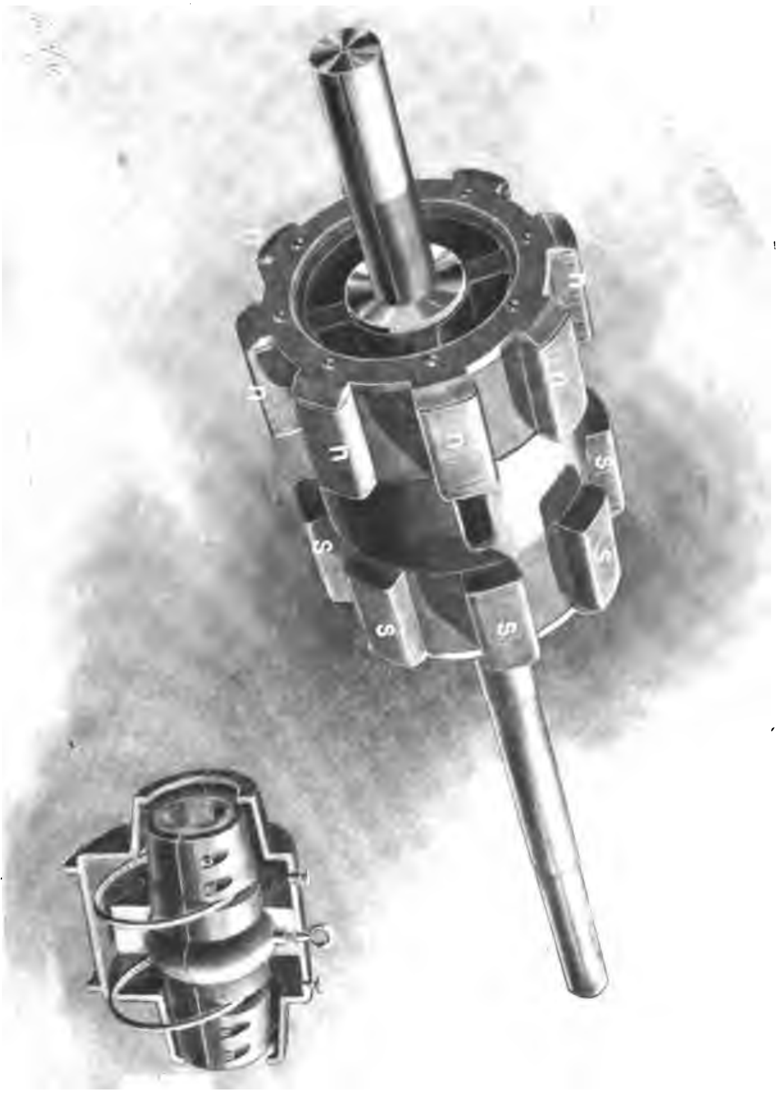


Fig. 202.—Inductor of S. K. C. Generator, with View of Bearing.

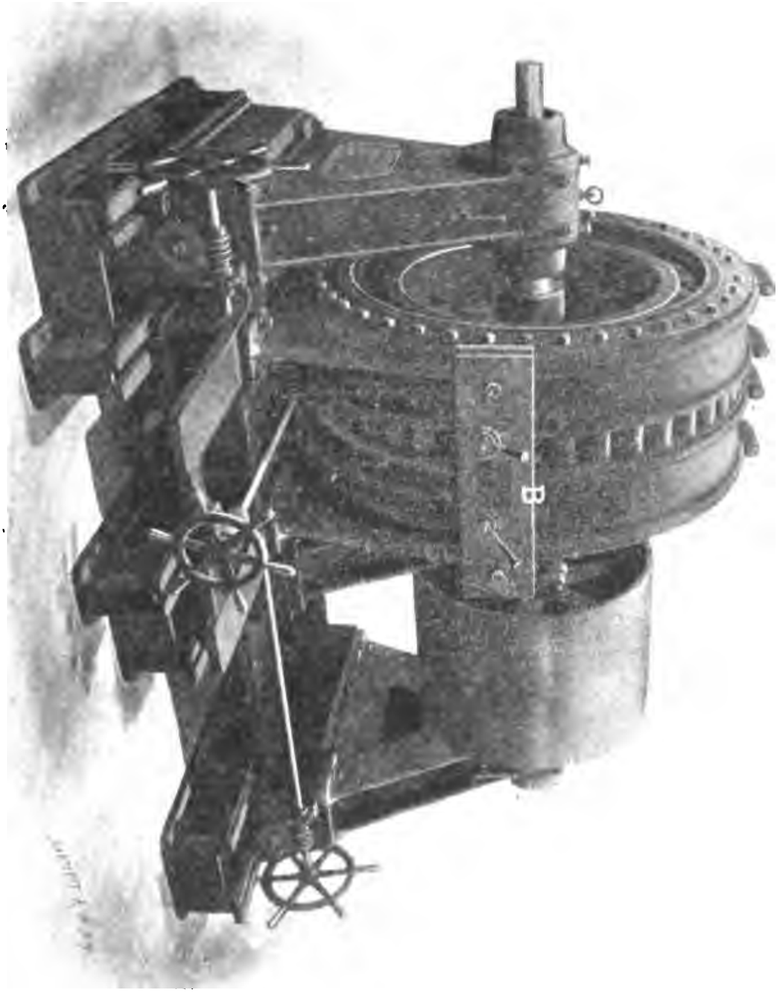


Fig. 203—Belt-Driven 240-K.W., S. K. C. Bi-Phase Generator.

projections at one end are, say of north polarity, and all the projections at the other end, of opposite or south polarity, under the influence of the magnetizing coil, which is wound over the central portion of the steel cylinder Y. This machine is of the inductor type, as no copper wire is rotated in it.

The method of construction enables the armature coils to be readily replaced in case of accident to them.

Fig. 203, shows a belt-driven 240-K. W. S. K. C. diphaser, with wheel handles for belt-tightening and armature opening. The terminal board B, is provided with two marble panels, to receive the field and armature terminals. The interior space is separated into compartments for convenience in insulation. The two handles shown on this terminal board are for the purpose of varying at will, within certain limits, the pressure of each of the two diphase circuits by cutting in or out some of the armature coils. By changing the connections at this terminal board, the pressure of the machine can be varied from 1,000 to 2,000 volts in each circuit.

The diphase and triphase systems were introduced almost entirely for the purpose of being able to operate alternating-current motors on the distribution system. Prior to the introduction of multiphase systems, uniphase generators could be operated as motors under suitable conditions, provided they were first brought up to speed before being connected with the circuit. In other words, a uniphase generator will not start from rest as a motor, when connected with uniphase mains, but must first be started. This introduced a serious difficulty in all commercial applications in which the motor was required to stop and start at comparatively frequent intervals. A combination system has, however, since been developed by the General Electric Company called the *monocyclics ystem* The *monocyclic generator*, or *monocycler*, is a uniphaser provided with an additional small *teaser coil*, wound in diphase relationshipwith the main uniphase coil, and connected to the centre of the same. A monocylic generator has, therefore, three collector rings; two for the ordinary uniphase coil, and the third for the free end of the small teaser coil. By this means a single pair of wires, taken from the uniphase coil, will enable ordinary uniphase incandescent lighting to be carried on. Where, however, a triphase motor has to be operated, a third, or *power wire*, usually of smaller size than the main uniphase wires, is carried to the premises where the motor is installed, and by the aid of two suitably connected transformers, triphase currents are obtainable from the combination of the uniphase and power wires, for the purpose of operating the motor. The monocyclic system, therefore, possesses in a

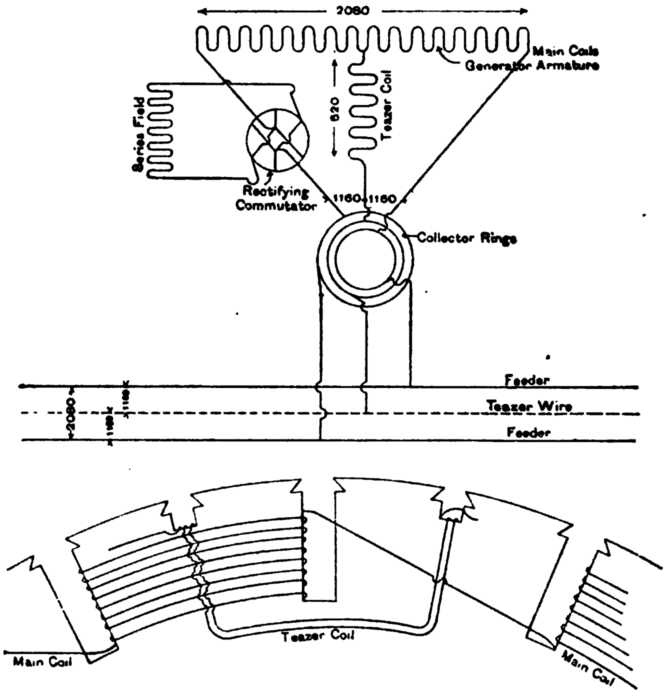


Fig. 204—Diagram Representing the Internal Connections of a Monocyclic Generator.

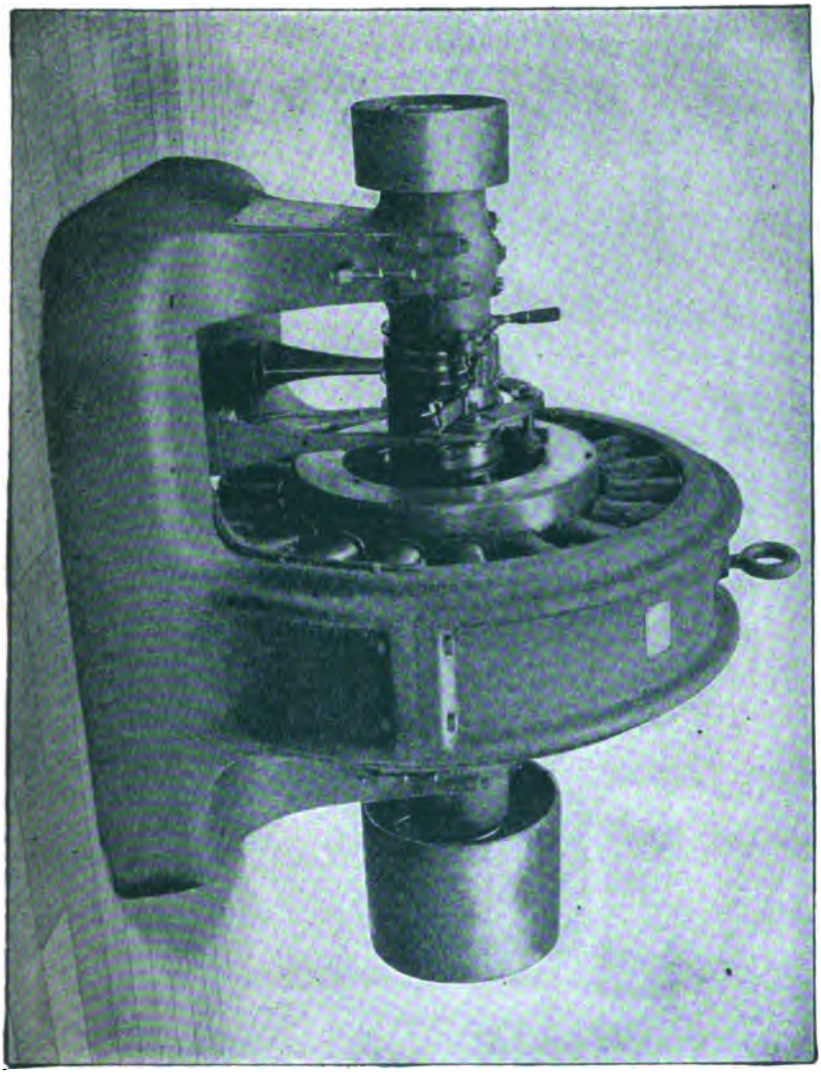


Fig. 205—"General Electric" 150 K. W. Standard Monocyclic Generator.

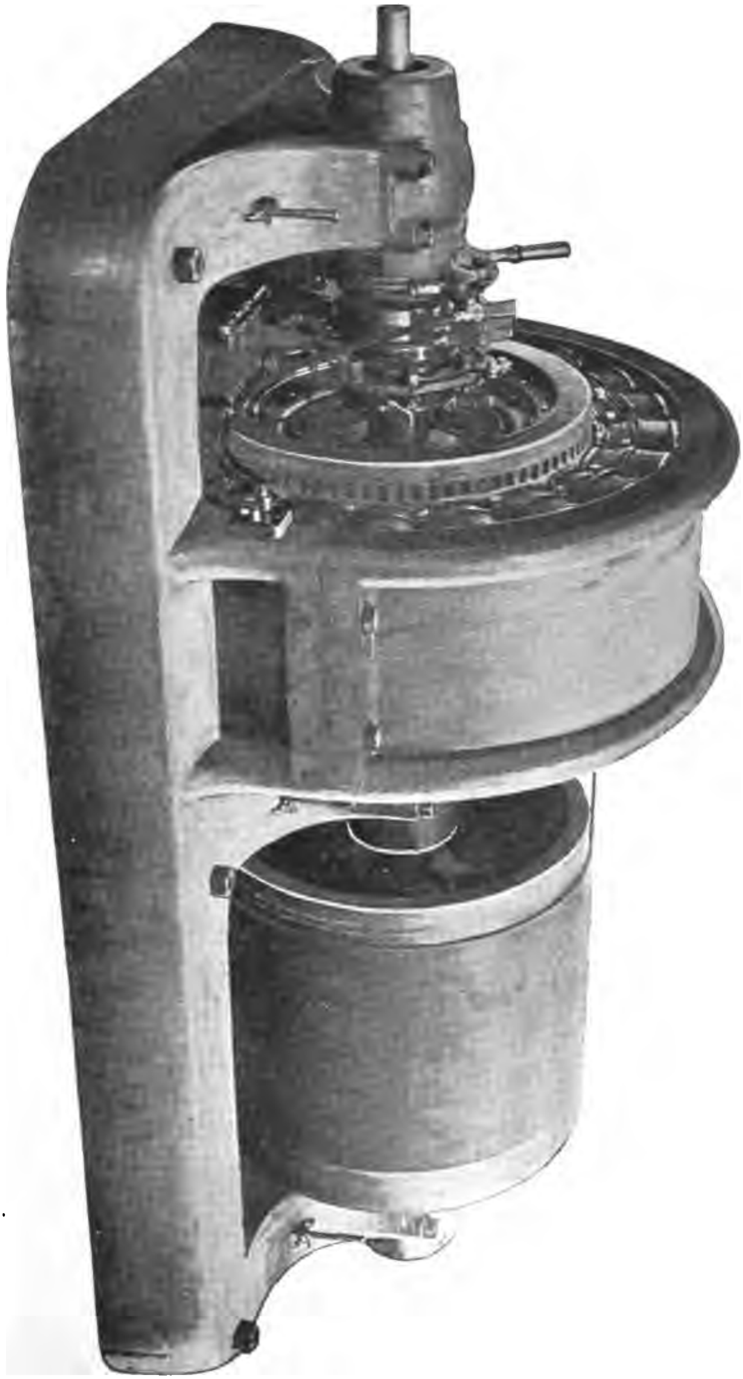


Fig. 208—"General Electric" 300-K. W. Standard Monocyclic Generator.

large degree the simplicity of the uniphase system, with the advantage of being able to supply triphase motors where needed, in connection with a general lighting system. It possesses advantages, therefore, for systems of distribution of both light and power.

Fig. 204, diagrammatically represents the connections of a monocyclic dynamo. AA, is the main armature winding, similar to that of an ordinary uniphaser, and producing a pressure of, say, 2,080 volts. bb, is the small teaser winding, connected in diphase relationship with the main winding and to the centre of the latter. The pressure in bb, is about 520 volts, which is not only about four times less than the pressure in the main winding, but the impulses in bb, are out of step, or in diphase relation to the impulses in the main winding AA. The series field is in the main circuit of the winding AA, and between this winding and the collector rings, which in their turn are connected by brushes with the three external conductors. The mechanical arrangement of winding is represented at the lower part of the figure. It will be seen that the teaser coil is wound in slots crossing the centres of the polar projections around which the main winding is placed.

Fig. 205, shows a General Electric Company's eighteen-pole 150 K.W. belt-driven standard monocyclic generator, which runs at 885 revolutions per minute and, therefore, has a frequency of 7,500 alternations per minute, or 125 cycles per second. It is compound-wound, and has three collector rings and a commutator. The principal excitation is provided by a separate exciter, while the armature current is in part commuted and supplied as compound excitation to the field magnets.

Fig. 206, shows a General Electric Company's 300-K. W. standard belt-driven monocycler, wound for a maximum pressure of 1,150, 2,300 or 3,450 volts. It has 20 poles, and runs at 360 revolutions per minute, having, therefore, a frequency of 60 cycles per second. It is compound wound, weighs 45,800 pounds, and occupies a space of 90 × 156 inches, × 67½ inches in height. The pulley is 53 inches in diameter with 44 inch face.

For slow-speed driving, some monocyclic generators are built with a great number of poles. Fig. 207, shows a standard 72-pole, 500-K.W. generator, driven directly, at a speed of 100 revolutions per minute, or a frequency of 60 cycles per second, and delivering 1,200 volts. The armature is wound with strip copper on edge.

Fig. 208, shows a 80-pole, 800-K.W. monocyclic Generator, directly coupled to a Corliss engine, and running at 90 revolutions per minute, with a frequency of 60 cycles per second.

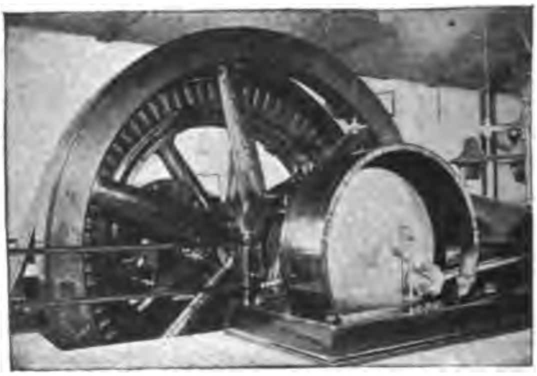


Fig. 207—"General Electric" 500-K. W. Monocyclic Generator.

The armature is 16 feet in diameter, and weighs nearly fifty tons. It is built in four sections. Half of the field of this machine is shown in Fig. 209. Its diameter is 24 feet, and the weight of the entire field, 66 tons. The field poles are of laminated steel cast into the field frame. The operation of boring an entire field frame is illustrated in Fig. 210. Here, an Edison bipolar motor drives the boring engine by a short belt.

The connections of a monocyclic generator with its distributing system are illustrated diagrammatically in Fig. 211. G, is the belt-driven monocyclic generator. 1 and 2,

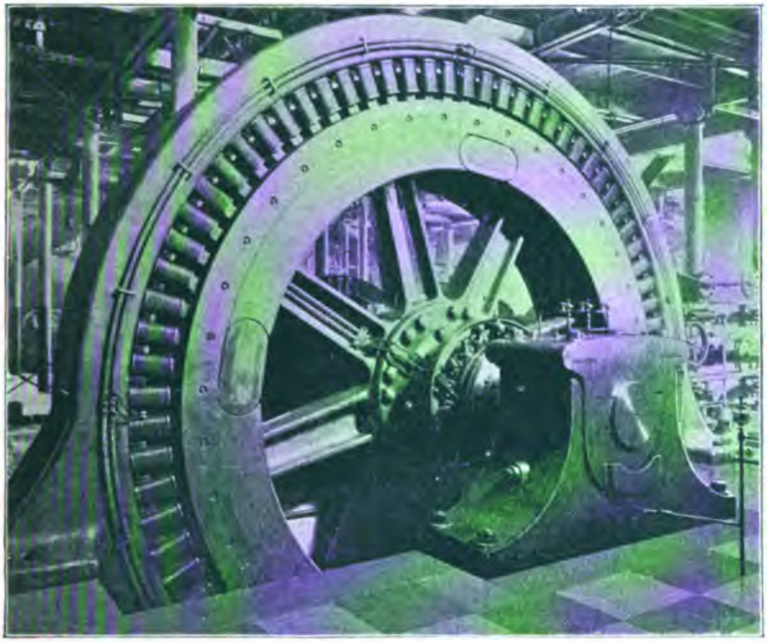


Fig. 208—"General Electric" 800-K. W. Direct-Driven Monocyclic Generator.

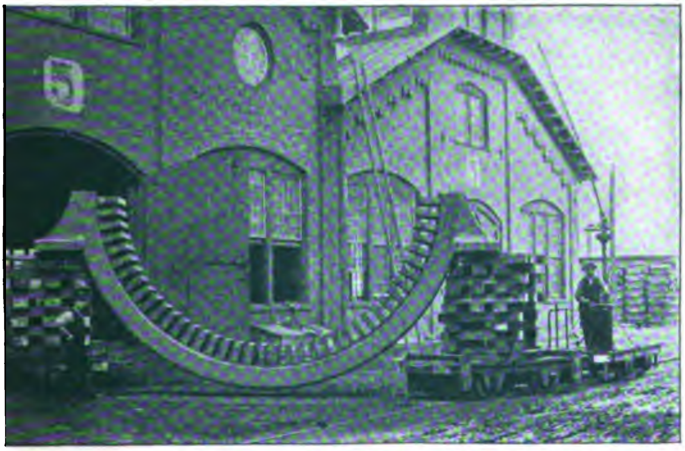


Fig. 209—Field Frame of "General Electric 800 K. W. Direct-Driven Monocyclic Generator.

are the main transmission wires, operated at, say, 2,000 volts. The dotted line p, shows the power wire, which may be of half the cross-section of either of the other wires. t_1, shows a step-down transformer with its primary connected across the mains 1 and 2, and supplying incandescent lamps on the three wire system at, say, 220 volts in all, or 110 volts on each side. t_2, is a step-down transformer, supplying arc lamps in parallel at, say, 30 volts. t_3, is a step-down transformer, supplying incandescent lamps at 110 volts, on the two-wire system, and also operating a small alternating-current fan motor. t_4, is a step-down transformer operating both incandescent lamps and arc lamps on the two-wire system at, say 110 volts. T_1', T_1, are two step-down transformers connected not only to the mains 1 and 2, but also to the power wire p, and from which triphase currents are supplied to the induction motor M_1. T_2, T_2, are a pair of step-down transformers, also connected with the power wire, and supply-

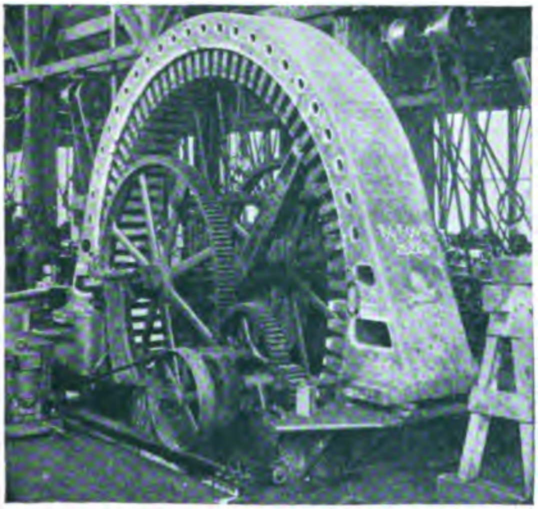


Fig. 210—Boring the Field Frame of "General Electric" 800-K. W. Monocyclic Generator.

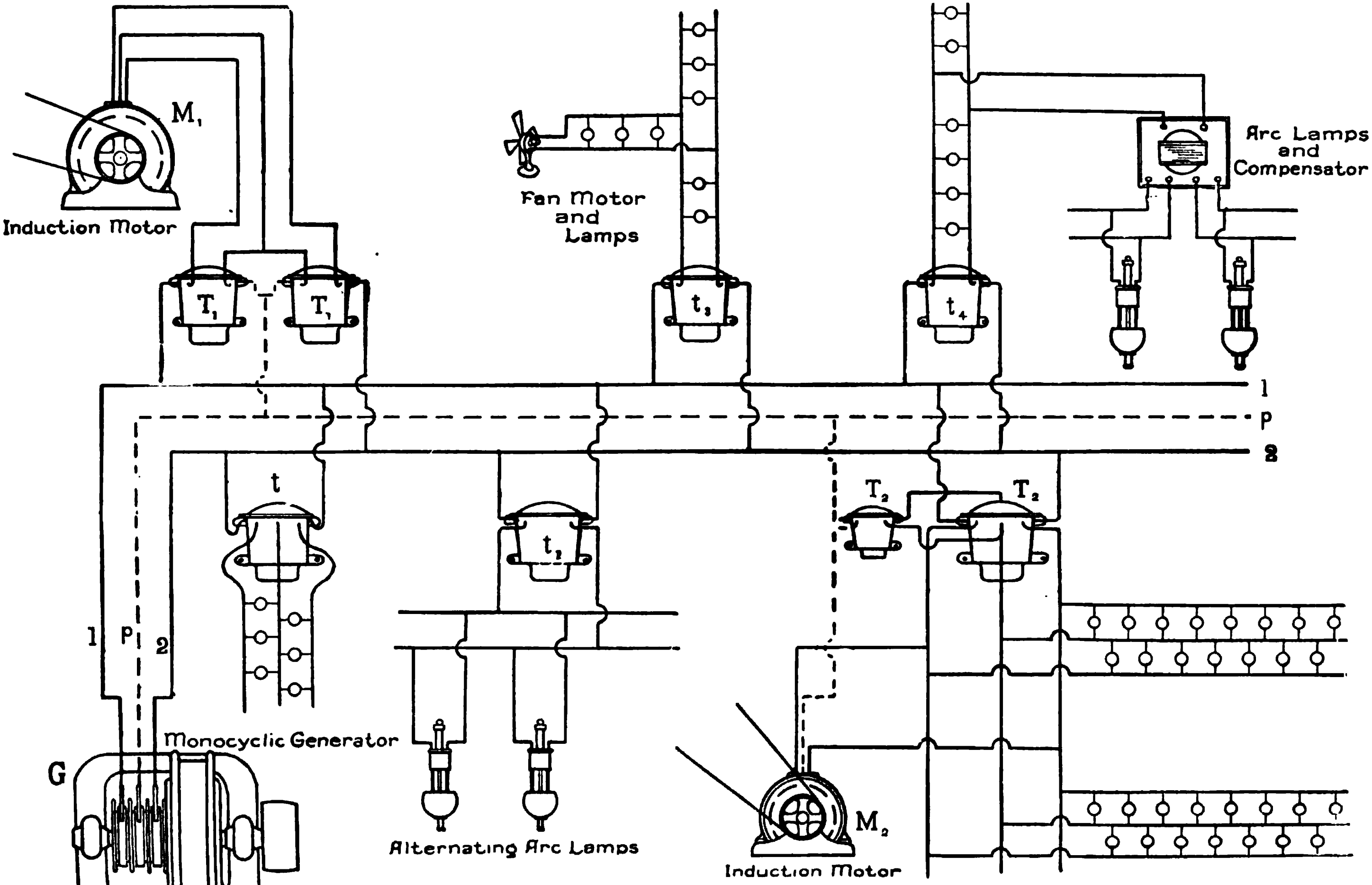


Fig. 211. Connections of Monocyclic System.

ing, in secondary circuits, incandescent lamps on the three-wire system and a triphase induction motor M_2.

The dimensions of standard monocyclic generators are the same as those of the standard triphasers given in the table on page 290, in connection with Fig. 196.

Alternators, whether uniphasers or multiphasers, should always be set up in a cool, dry and clean place, upon solid foundations. The frame work of a belt-driven alternator should be insulated, whenever possible to do so. This is usually accomplished by capping the masonry, or brick foundation, with a varnished wooden base bolted to the masonry, and then bolting the alternator frame to the wood work by separate bolts. The base on which the frame rests should be carefully levelled, and the machine should be set with its shaft and pulley in accurate relation with the driving shaft and pulley.

The commutator should be kept smooth by the application of fine sand-paper at suitable intervals, but this should not be applied until the brushes are lifted. The brushes should be kept in proper shape and condition. Their pressure on the commutator surface should receive careful attention. Too much pressure is apt to produce a cutting of the commutator surface, and too little pressure is apt to produce sparking. The surface of the commutator may occasionally be lubricated by a small quantity of vaseline applied by a cloth, but never applied by cotton waste.

Should a hot bearing develop, heavy oil should be at first copiously applied, and the belt slackened as far as may safely be permitted. When a new alternator is started, it should be run slowly for some time, to see that its bearings are in proper condition, and that it operates without undue heating. It is also well to run a recently shipped alternator for a day, unexcited, so as to thoroughly dry out the armature. When an alternator is started, the bearings should always first be examined to see that they have a plentiful supply of oil. When the machine is not running, its brushes should be lifted. After starting, the brushes are lowered. The machine is then brought up to speed. The exciter circuit is closed, and the pressure generated by the machine is then adjusted by the field rheostat. The load is then thrown on the machine and the commutator brushes are adjusted to the non-sparking position. After the machine is stopped, it should be cleansed of oil and dust. Copper dust, if allowed to accumulate, may injure a machine.

CHAPTER IX.

ALTERNATING-CURRENT TRANSFORMERS.

THE alternating-current transformer is a very important piece of apparatus since it not only enables electric power to be transmitted to a great distance at a high electric pressure, and, consequently, at a low cost in copper, but it also permits of the ready reduction of that pressure to safe and convenient limits, at the point of delivery.

All alternating-current transformers consist essentially of a primary and a secondary coil which are electrically insulated from each other, but which are magnetically connected through the medium of a laminated magnetic core, common to both. In other words, the coils are so placed that while the current which flows through one is unable to flow through the other, yet the magnetism or magnetic flux produced by one is threaded through the coils of the other. By this means an induced pressure is generated in the other coil. The coil which receives the current to be transformed is called the *primary coil*, while the coil which delivers the transformed current is called the *secondary coil.*

Fig. 212, shows a Stanley transformer for 125 lights, or 6.25 K.W., allowing 50 watts to a 16-candle power incandescent lamp. P, P, are the primary wires connected with the primary mains of, say 1050 volts pressure. S, S, are the secondary mains issuing from the secondary coil, and connected to the lamp circuit, at a pressure of, say 105 volts. In order to obtain a transformation from 1050 to 105 volts, there must be, approximately, ten times fewer turns in the secondary coil than in the primary. FF, is the fuse block into which the primary wires enter and which opens by a door beneath, secured by a thumb-screw. Although the secondary turns are ten times fewer in number than the primary turns, yet the cross-section of the wire in the secondary coil is much greater than the cross-section of the wire in the primary coil, so as to permit a more powerful current to be supplied under the lower pressure in the secondary circuit. The weight of wire in the primary and secondary coils and, therefore, the space occupied by the wire, apart from the insulation, are roughly the same.

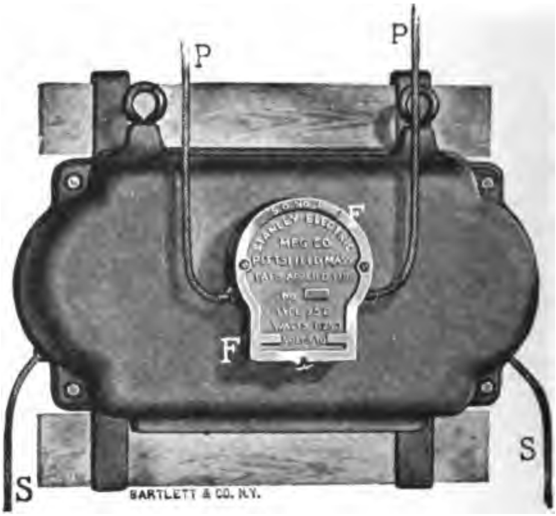


Fig. 212—"Stanley Electric" 125-Light Alternating-Current Transformer.

The details of the fuse box are shown in Fig. 213. As will be seen, the box is divided into two compartments, one for the positive connection, and the other for the negative. Into each compartment there fits a porcelain wedge W. On one side of this wedge, is a pair of spring clips which fit into corresponding metallic recesses, when the wedge is pushed into its receptacle. On the other side of the wedge is a fuse wire, fitting in a groove between two binding posts, each in connection with one of the spring clips. By this means the fuse wire is made to bridge across the gaps between the recesses in the fuse box, and so close the circuit.

More recent types of these Stanley fuse-blocks are shown in Figs. 213 A, and 213 B. Fig. 213 A, shows a form similar to that of Fig. 213, but with the fuse wire slipped through an insulating tube, instead of lying in a groove in the porcelain block. Fig. 213 B, shows a cylindrical form of fuse-holder in a groove at the tip of the cylinder.

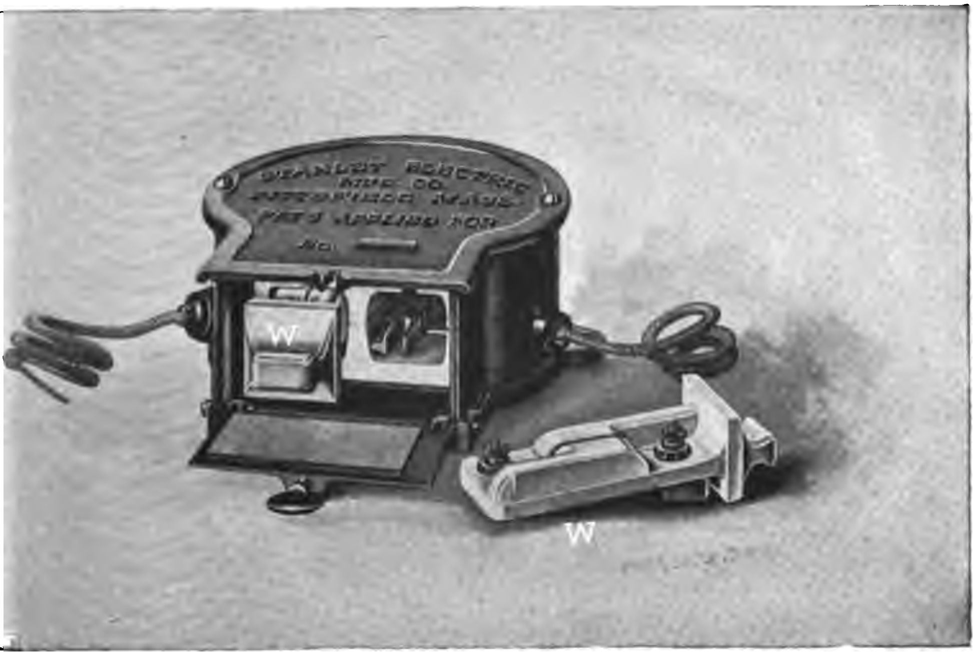


Fig. 213—Details of "Stanley Electric" Transformer Fuse-Box.

A 25-K.W. 500-light Stanley transformer, of the indoor type, is shown in Fig. 214. Such a transformer is usually placed in the cellar of the house it is intended to supply. Here, the primary wires enter the transformer at the left-hand, and the secondary wires emerge on the right-hand.

Fig. 215, shows a large high-voltage Stanley transformer, insulated with oil. The transformer itself is placed inside the tank shown, which is then filled with oil and the lid screwed down. Oil is very often used at the present time for the insulation of transformers. It is very important that the insulation of the transformer coils shall be carefully maintained, both from the iron core and from each other. This is especially the case with high-voltage transformers. Any accidental static discharge, such as a discharge due to lightning, which might destroy an ordinary air-insulated transformer, might be safely withstood by an oil-insulated transformer; since, if the oil insulation is pierced, it at once mends itself.

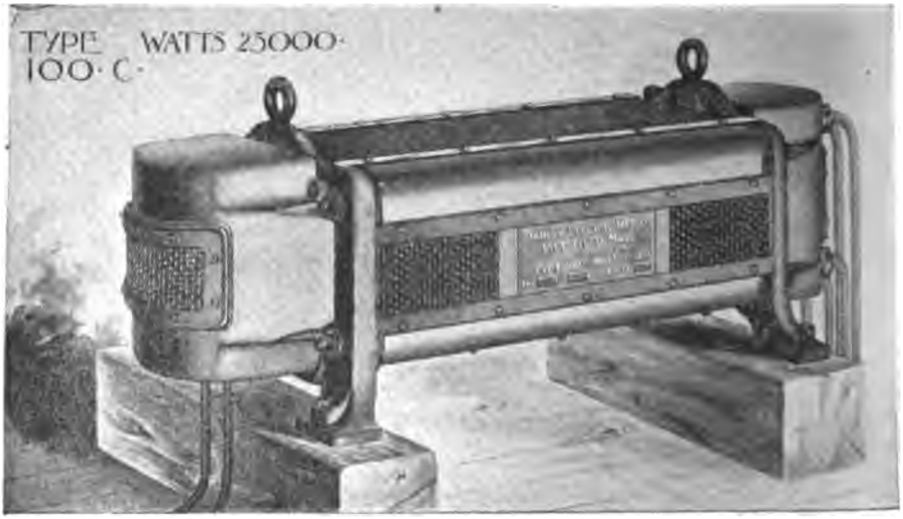


Fig. 214—25 K. W. "Stanley Electric" Alternating-Current Transformer.

Transformers are divided into two sharply marked groups; viz.: *air-cooled*, and *oil-cooled*. Air-cooled transformers, when in large sizes, are aided in throwing off their heat by a blast

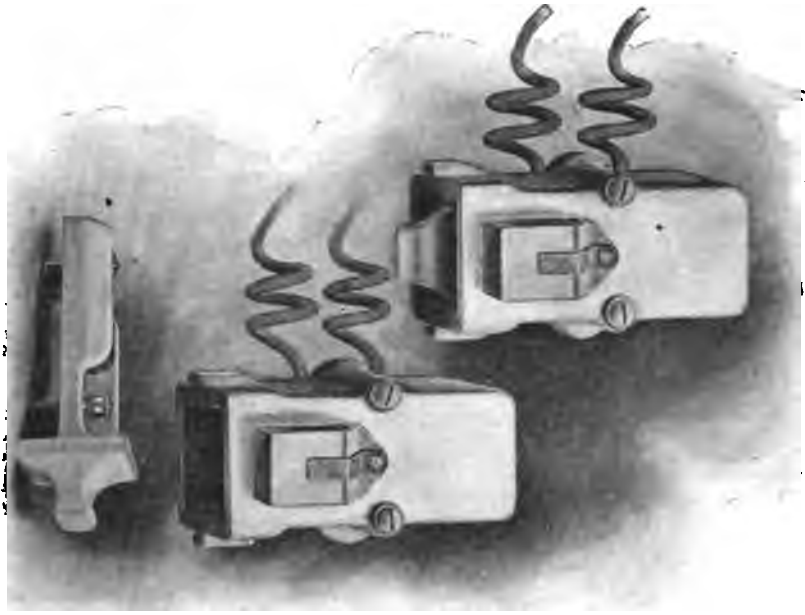


Fig. 213 A—Recent Type of "Stanley" Fuse-Blocks.

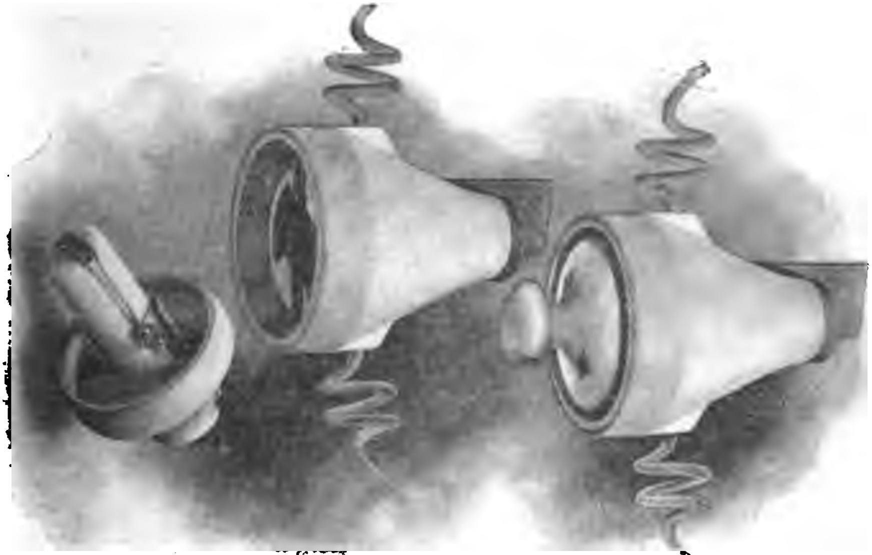


Fig. 213 B—Recent Type of "Stanley" Fuse-Blocks.

of air. Oil-cooled transformers in large sizes are aided by special attention to the circulation of the oil, and by a forced circulation of cold water through pipes in the transformer casing.

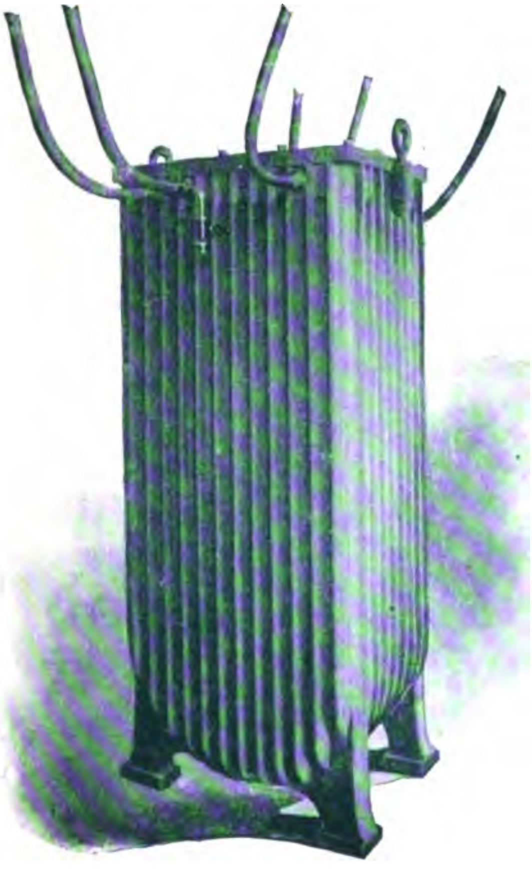


Fig. 215—High-Voltage "Stanley Electric" A. C. Transformer.

The size and weight of a transformer increase with the load that it has to carry. The weight, however, does not increase in the same proportion as the capacity. The necessity for increasing the size of a transformer arises from the fact that the wires must necessarily be increased in cross-section, in order to safely carry more powerful currents. This increase in the size of the wire necessitates increase in the size of the iron core to make room for them.

Fig. 216, shows a Westinghouse Electric Company's 75-K.W. oil-cooled transformer. In this machine, there are six coils, all carefully insulated from the iron frame and from each other. p, p, are the two primary coils, and s, s, s, are the four secondaries. Instead of placing a single primary coil alongside a single secondary, it is often preferable to intersperse the primary and secondary coils in this manner, in order to improve the regulation of the transformer, even at the expense of increased care in insulation; since by this

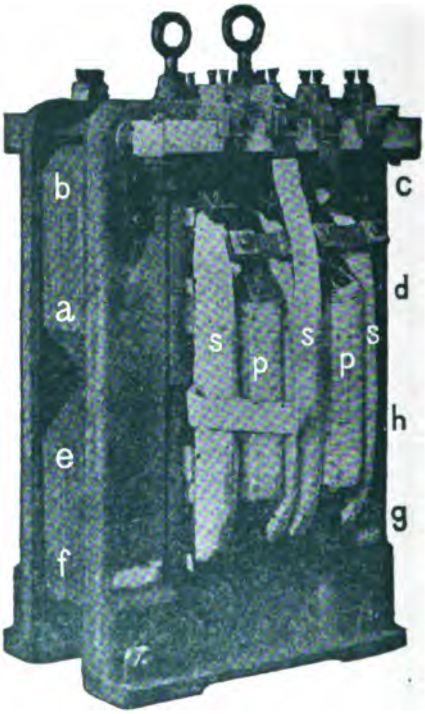


Fig. 216—"Westinghouse" 75 K. W. A. C. Transformer.

means the magnetic leakage is reduced, more of the magnetic flux linked with the primary coil being obliged to pass through the secondary. The laminated iron core,

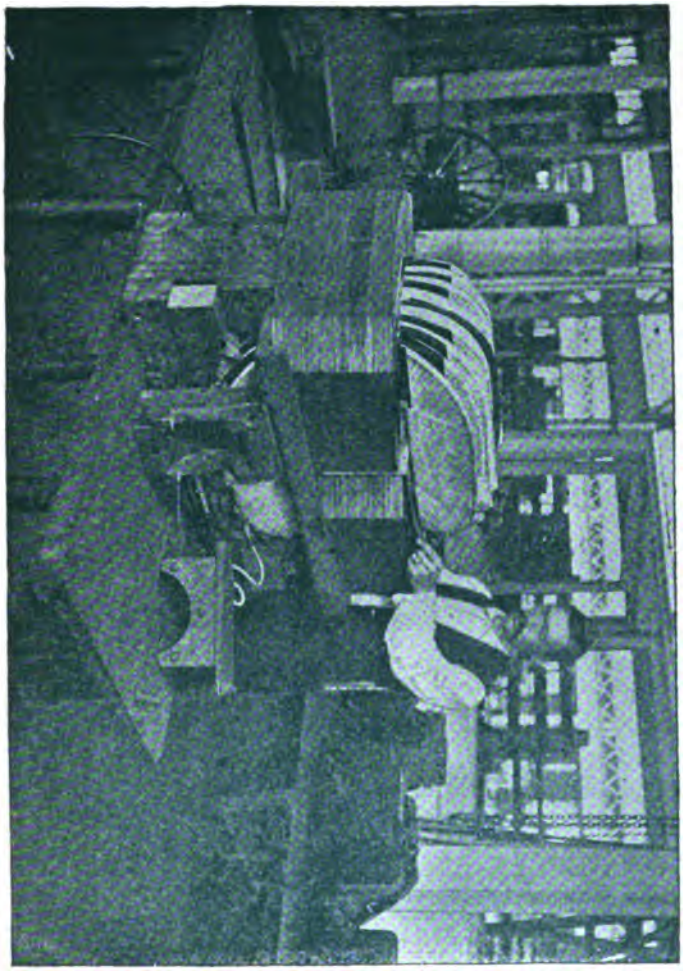


Fig. 217—Method of Building Large Transformers.

around which the coils are placed, is divided into two branches, each of which completes its own magnetic circuit, one branch passing completely around the coils at a, b, c, d, and the other branch, at e, f, g, h.

Fig. 217, shows the method of building up the magnetic circuit of a large transformer. There are eight flat coils of insulated copper wire, all carefully insulated. Sheets of soft steel, in the form of open rectangles, are slipped through the coils, alternately from opposite sides until the entire core

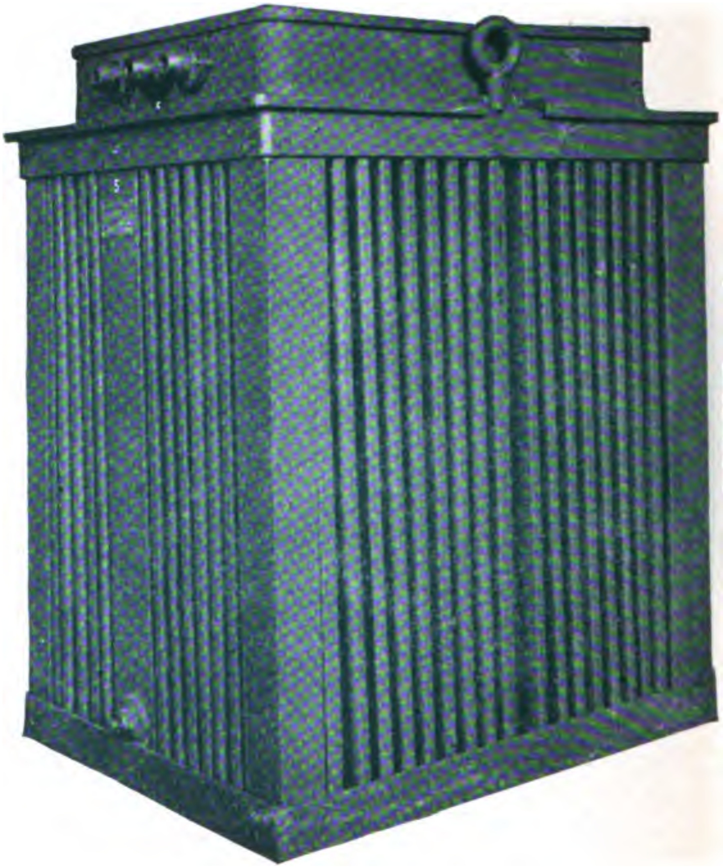


Fig. 218—Case for 150-K. W. "Westinghouse" Transformer.

is built up. The iron core of a transformer is always laminated, because the magnetic flux, which passes through it, oscillates or moves to-and-fro, with the frequency of the alternating current, and would, if solid cores were employed, set up powerful and wasteful ***Foucault currents***, or eddy currents, in the mass of iron.

After one of these transformers is built, and has been carefully tested, it is placed in its cast iron case and immersed in oil. Fig. 218, shows the case for a 150 K.W. Westinghouse transformer.

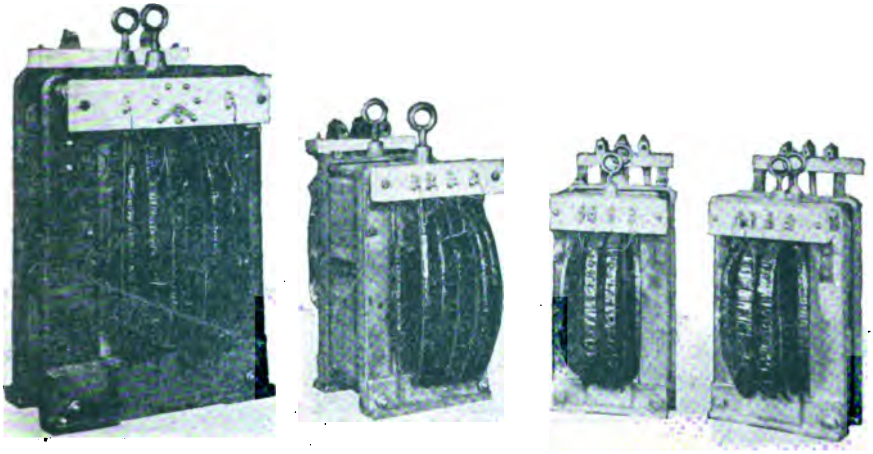


Fig. 219—10,000-Volt "Westinghouse" Transformer.

Fig. 219, shows an assemblage of four 10,000-volt, oil-cooled, Westinghouse transformers, of sizes varying from 10 K.W. up to 100 K.W. The largest of these transformers will, therefore, receive at its primary terminals about ten amperes at 10,000 volts pressure, and will deliver at its secondary terminals about 100 amperes at 1,000 volts pressure, or about 1,000 amperes at 100 volts pressure, according to the nature of the secondary winding.

The vertical position of the coils in the case facilitates the circulation of the oil. The ends of the coils are spread apart, so as to offer a large surface to be cooled by the circulating oil. The corrugation upon the external and internal surfaces of the cast-iron casing greatly assist in conducting the heat from the oil within, and disengaging it by radiation and convection to the external air.

The dimensions and weights of the principal standard sizes of Westinghouse oil-cooled transformers and cases, are given in the accompanying table.

DIMENSIONS AND WEIGHTS OF WESTINGHOUSE SELF-COOLING TRANSFORMERS AT 7,200 ALTERNATIONS PER MINUTE, AND UP TO 15,000 VOLTS.

Capacity in K.W.	DIMENSIONS.		WEIGHT.			Total.
	Floor Space.	Height.	Transformer.	Case.	Oil.	
10	20″ x 30″	34″	350	250	210 (30 gal.)	810
25	22″ x 32″	34″	500	325	280 (40 ")	1105
50	25″ x 35″	40″	750	475	385 (55 ")	1610
62½	25″ x 35″	40″	900	475	350 (50 ")	1725
75	29″ x 38″	47″	1050	625	525 (75 ")	2200
100	32″ x 38″	52″	1450	725	665 (95 ")	2840
125	32″ x 38″	52″	1650	725	630 (90 ")	3005
150	34″ x 38″	56″	1800	850	700 (100 ")	3350
200	36″ x 43″	60″	2200	1000	770 (110 ")	3970
300	38″ x 48″	62″	2500	1300	840 (120 ")	4640
375	40″ x 52′	63″	2800	1500	980 (140 ")	5280
500	45″ x 58″	68″	3200	1750	1120 (160 ")	6070

The efficiency of transformers; i. e., the ratio of the electric power delivered at secondary terminals, to the electric power absorbed at primary terminals, is, in the case of large transformers, particularly important, since a low efficiency means a large waste of energy as heat. This would not only be detrimental on account of the cost of the power wasted, but also on account of the increased difficulty of keeping the machine cool. The following data concerning the efficiency of fairly large Westinghouse transformers indicates how little margin actually remains for improvement in this direction.

TABLE OF EFFICIENCIES OF WESTINGHOUSE TRANSFORMERS OF E. M. F. FROM 500 TO 15,000 VOLTS, WITH FREQUENCY OF 7,200 ALTERNATIONS PER MINUTE,

DELIVERY AT FRACTIONAL PART OF FULL LOAD.

CAPACITY 150 K. W.

Fractional Load,	0.1	0.2	0.3	0.4	0.5
Efficiency,	0.90	0.945	0.957	0.965	0.97
Fractional Load,	0.6	0.7	0.8	0.9	1.0
Efficiency,	0.975	0.976	0.977	0.978	0.98

CAPACITY 375 K. W.

Fractional Load,	0.1	0.2	0.3	0.4	0.5
Efficiency,	0.93	0.965	0.97	0.975	0.98
Fractional Load,	0.6	0.7	0.8	0.9	1.0
Efficiency,	0.982	0.984	0.985	0.985	0.985

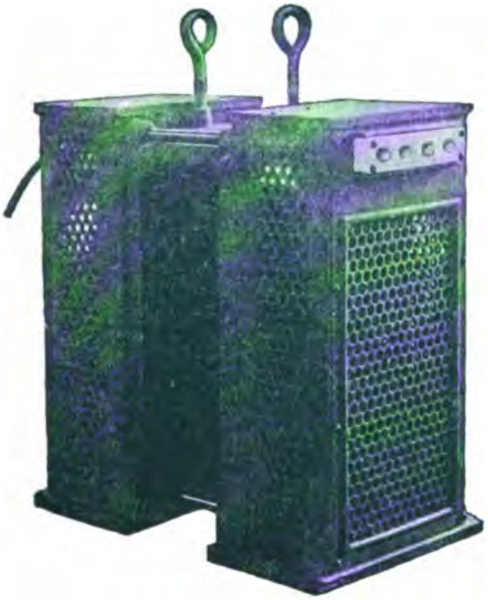


Fig. 220—25 K. W. "Westinghouse" Transformer.

Thus, at half load, a 150 K. W. transformer has an efficiency of 0.97, or 97 per cent, and, therefore, wastes or loses 3 per cent of the power it absorbs from the primary circuit.

Fig. 220, shows an air-cooled, 25-K.W. Westinghouse transformer for indoor installation. The transformer is supported in an iron frame provided with gratings to allow the free admission and circulation of air.

Fig. 221, shows the same transformer with end casings removed. There are seen to be six coils, four primaries and two secondaries. The secondaries are of strip copper, wound on edge, in the form of a flat spiral. The coils of such a transformer, before assembling on the laminated core, are shown in Fig. 222. These coils are wound in suitable forms of many layers with very few turns in each layer. They are thoroughly insulated with mica, fibre, and tape.

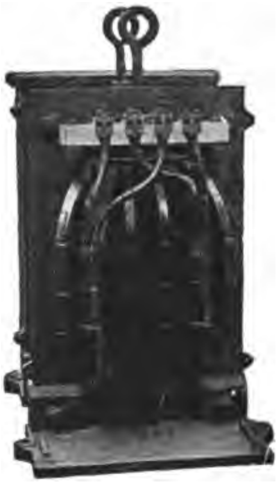


Fig. 221—25 K. W. "Westinghouse" Transformer. End Casing Removed.

Small air-cooled transformers, suitable for suspension out-of-doors, are contained in cast-iron cases. A form of 7.5 K.W. Westinghouse transformer, of the air-cooled type, is shown in Fig. 223.

Transformers are usually tested in the factory at double pressure, and at over-load, for insulation, regulation and heating.

The standard sizes of Westinghouse incandescent-lighting transformers have two secondary coils, each generating either

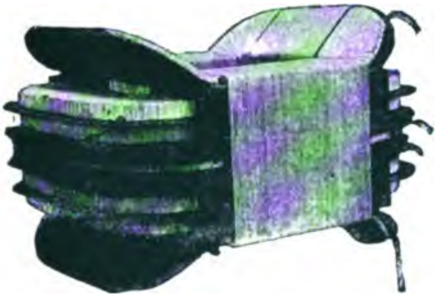


Fig. 222—"Westinghouse" Transformer. Coils Assembled.

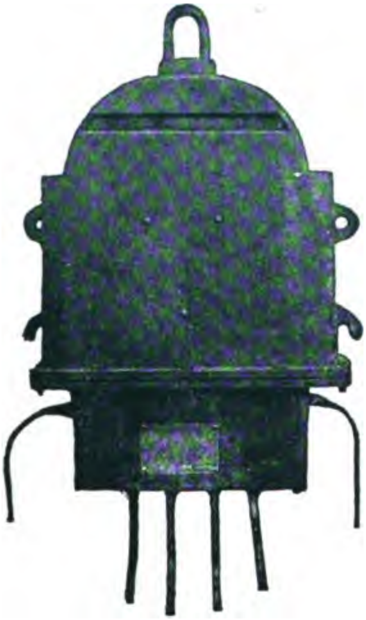


Fig. 223—"Westinghouse" 7 ½-K. W. Transformer.

50 volts or 100 volts, according to the type. These may be connected in series for 100 or 200 volts respectively. The

primary coils may be connected in series or in parallel for 2,000 or 1,000 volt primary pressure.

Fig. 224, shows a Westinghouse Electric Company's 750.

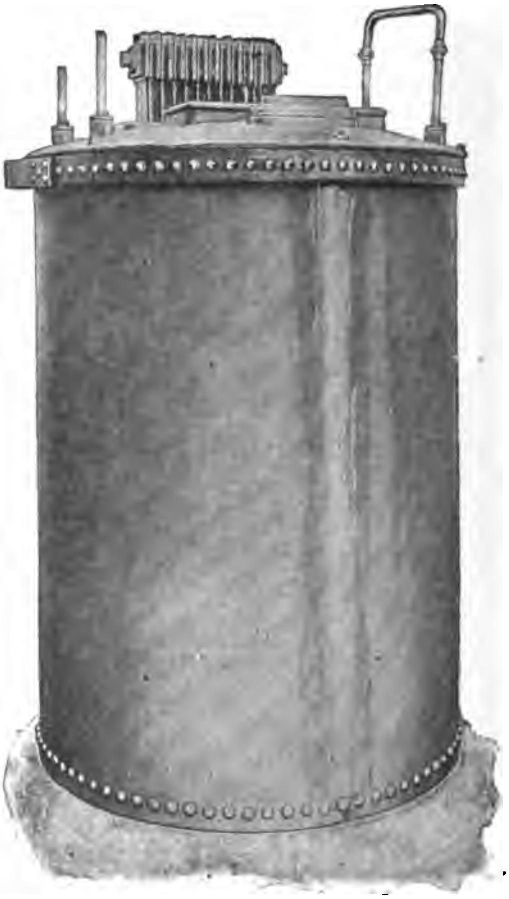


Fig. 224—"Westinghouse" 750-K. W. Transformer. Water Cooling Type.

K. W. transformer for reducing pressure from 2,200 to 110 volts. This transformer is cooled by the circulation of water supplied through the pipes shown.

Fig. 225, is an external view of a 375-K. W. Westinghouse transformer for 15,000 volts pressure. This transformer is of the self-cooling type. That is to say, it is immersed in oil and dissipates the heat generated by radiation and convection from the surface of the case. The interior of this

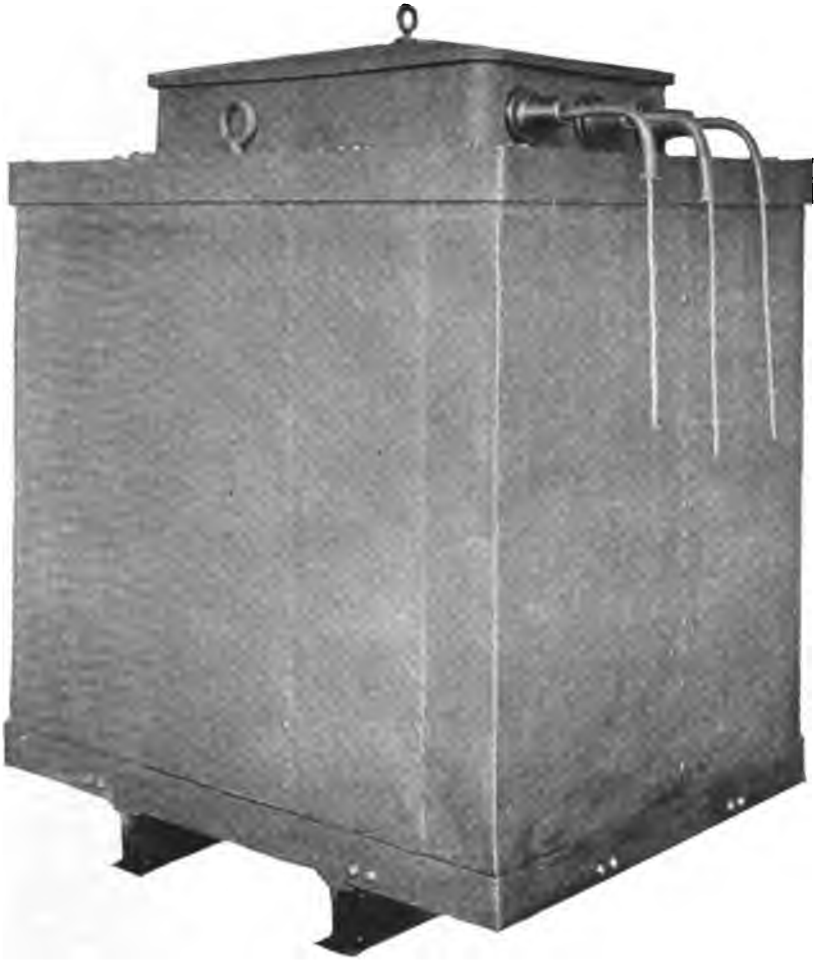


Fig. 225—Case for 375-K. W. 15000-Volt "Westinghouse" Transformer.

transformer is shown in Fig. 226. This apparatus transforms diphase currents to triphase currents, or vice-versa. The high-tension, or triphase terminal board is shown at bb, and the low-tension or diphase terminal board at BB.

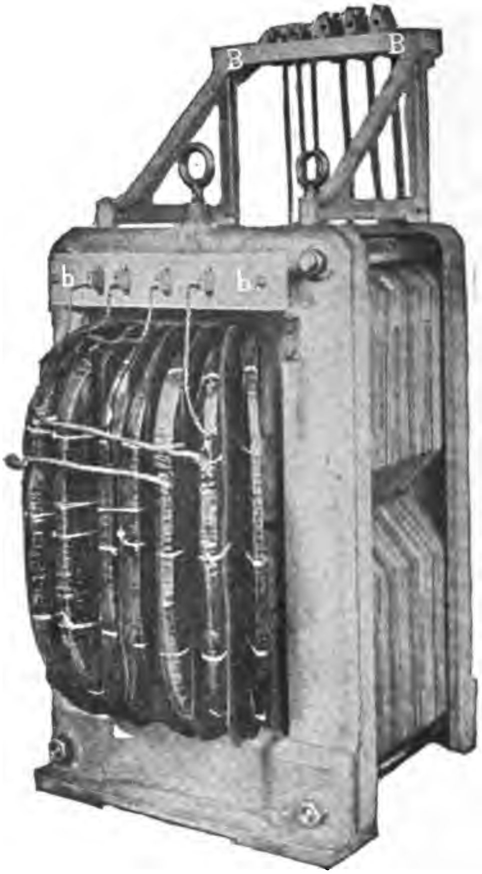


Fig. 226—Interior of 375-K. W. "Westinghouse" Transformer.

A pair of such transformers is installed for each transformation from two-phase to three-phase distribution, or vice versa.

A Westinghouse transformer, for arc-lighting, is shown in

Fig. 227. These transformers are made in three standard sizes, for one, two, or three 16-ampere arc lamps respectively. The pressure at the primary terminals, is either 1,000 or 2,000 volts, according to connection, and is interchangeable as above described. The secondary pressure is from 30 to 37 volts, according to requirements.

The transformer fuse-box employed by the Westinghouse Electric Company is illustrated in Fig. 228. Four insulated wires are seen to enter the box from beneath. Two of these are from the primary mains, and the other two lead to the primary coil of the transformer. These wires terminate inmetallic receptacles r, r, r, r, secured in a porcelain plate. These pairs of receptacles are bridged over by fuse wires contained in porcelain tubes shown above the box. The wires are connected between metallic spring tubes p, p, which fit into the receptacles r, r. Should a short circuit or sudden overload occur in the transformer, the arc, formed on the blowing of the fuse, is almost immediately extinguished by the violent rush of air through the outlet tube o, consequent upon its expansion by the heat of the arc. The arc is thus ingeniously made to blow itself out.

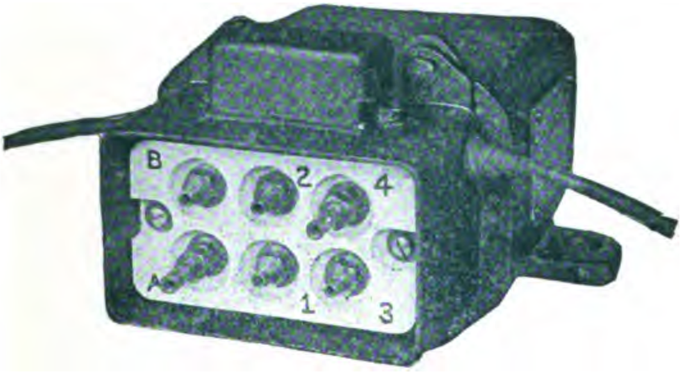


Fig. 227—" Westinghouse Transformer for Arc-Lighting.

The spring S, keeps the porcelain tubes firmly in place when the box is closed. The box is rendered weather-proof by the thumb-screws T, T.

Fig. 229, shows the type-F transformer, of the General Electric Company. The internal arrangement of the coils and core of this transformer is shown in Fig. 230.

The primary coil P, is on the inside, the secondary coil S, is on the outside, and they are necessarily thoroughly insulated from each other. A laminated iron core passes through both and completes a magnetic circuit on each side. The secondary coils are halved, or divided into two sets, for coupling in series or in parallel. The rated efficiencies of these transformers, at a frequency of 125 cycles per second, in different sizes and at different proportions of full load, are given in the accompanying table.

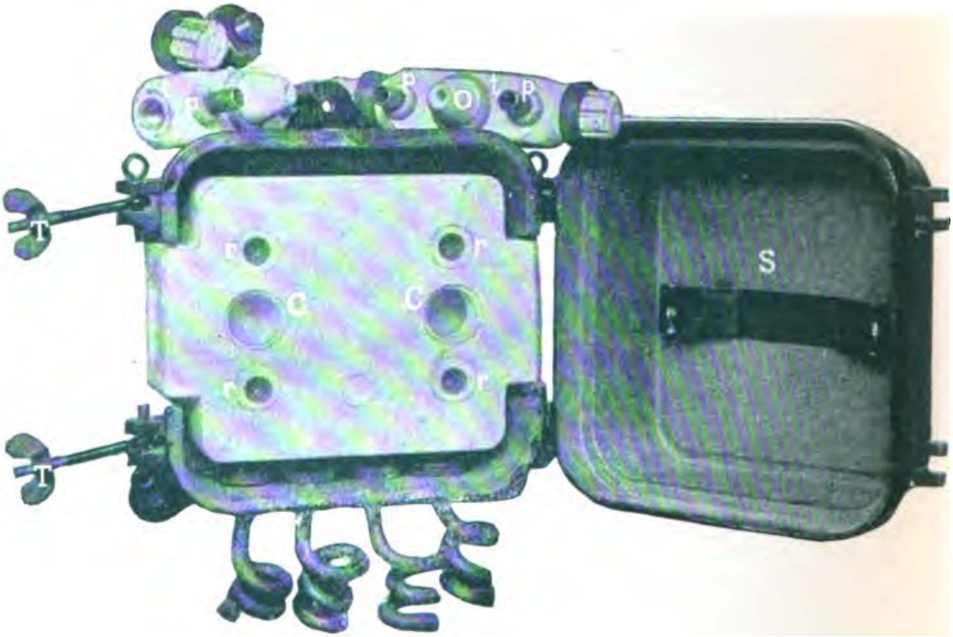


Fig. 228—"Westinghouse" A. C. Transformer Fuse-Box, Opened, Tubes Removed.

Thus, the largest transformer tabulated; namely, the 30-K.W. transformer, is stated to have a full-load efficiency of $97\frac{7}{10}$%; or, to have a loss of $2\frac{3}{10}$, representing 690 watts; while the smallest transformer, of 350-watts capacity, has an efficiency, at quarter-load, of 78.2%. The regulation of these transformers is given in the accompanying table, from which it will be seen that the percentage of drop, at secondary terminals, between no load and full load, amounts roughly to $2\frac{1}{2}$% on the average; so that if a transformer gives, say 100 volts at its secondary terminals under no load, it gives about

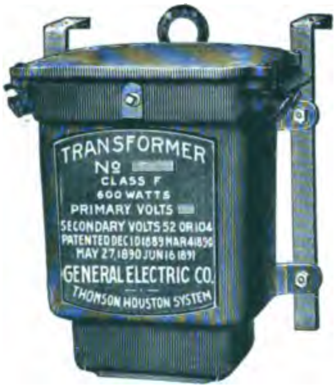


Fig. 220—"General Electric" Type F Transformer.

PERCENTAGE OF EFFICIENCY. GENERAL ELECTRIC COMPANY'S TYPE F TRANSFORMER, 125 CYCLES.

Capacity in Watts.	¼ Load.	½ Load.	¾ Load.	Full Load.	Capacity in Watts.	¼ Load.	½ Load.	¾ Load.	Full Load.
350	78.21	87.24	90.44	92.00	6000	92.83	95.76	96.38	96.77
600	84.10	90.95	93.00	93.90	7500	93.00	96.30	96.90	97.20
1000	88.20	93.00	94.00	94.80	12000	94.70	96.80	97.30	97.50
1500	90.00	94.00	94.95	95.23	15000	94.80	96.90	97.50	97.70
2500	90.25	94.32	95.45	95.74	20000	95.00	97.00	97.60	97.70
3500	93.00	95.70	95.80	96.50	30000	95.80	96.80	97.40	97.70
4500	93.50	96.30	96.85	96.96					

97½ volts at full load, the primary pressure being maintained constant.

REGULATION OF GENERAL ELECTRIC COMPANY'S 125-CYCLE TRANSFORMERS.

WATT CAPACITY.	VARIATION IN VOLTS.		WATT CAPACITY.	VARIATION IN VOLTS.	
	52 Volts.	104 Volts.		52 Volts.	104 Volts.
350	1.20 volt	2.40 volts	6000	1.40 volt	2.80 volts
600	1.20 "	2.40 "	7500	1.40 "	2.80 "
1000	1.30 "	2.60 "	12000		2.40 "
1500	1.40 "	2.80 "	15000		2.00 "
2500	1.40 "	2.80 "	20000		2.00 "
3500	1.25 "	2.50 "	30000		2.00 "
4500	1.40 "	2.80 "			

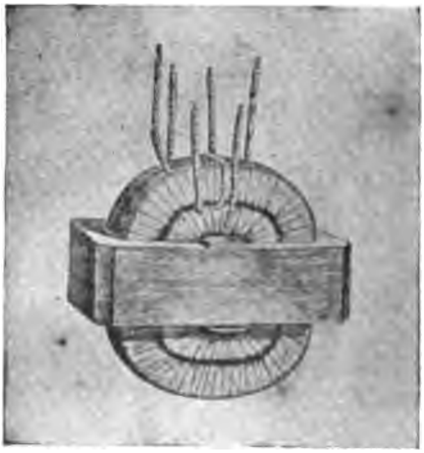


Fig. 230—Internal Arrangement of Coils and Core in Type F "General Electric" Transformer.

The regulation in the larger sizes is seen to be better than in smaller sizes.

Fig. 231, shows a 1,000 watt or 20-light transformer, of the General Electric Company's "F" type, and Fig. 232, shows a 30,000-watt transformer, of the same type. All these type "F" transformers are made so that they can be kept immersed in insulating oil. In sizes up to 7.500 watts, they are usually placed outside the building to be lighted and fixed upon the wall or pole. In sizes above 7,500 watts, they are usually placed in-doors. The dimensions and weights of these transformers is shown in the accompanying table and Fig. 233.

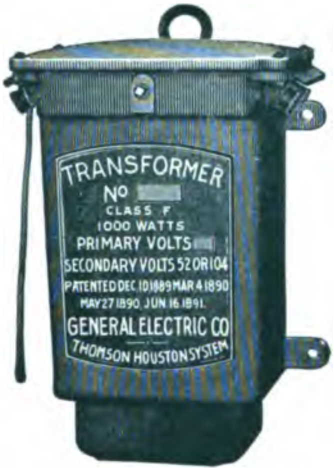


Fig. 231—"General Electric" 1-K. W. Type F, A. C. Transformer.

DIMENSIONS OF GENERAL ELECTRIC COMPANY'S TYPE "F" TRANSFORMERS.

	Watts.	Weight	A	B	C	D	E	F	G	Lights.	Oil.
F	600	66	$10\frac{1}{4}$	9	$6\frac{3}{16}$	$2\frac{3}{8}$	$12\frac{5}{8}$	$6\frac{7}{16}$	$13\frac{1}{2}$	12	2 qts
F	1000	85	$10\frac{1}{4}$	$9\frac{1}{4}$	$8\frac{15}{16}$	$2\frac{3}{8}$	$14\frac{7}{8}$	$6\frac{7}{16}$	16	20	$2\frac{1}{2}$ "
F	1500	117	$14\frac{3}{4}$	$13\frac{3}{8}$	6	3	13	9	15	30	$4\frac{1}{2}$ "
F	2500	144	$14\frac{3}{4}$	$13\frac{3}{8}$	$7\frac{1}{2}$	3	$14\frac{1}{2}$	$8\frac{7}{8}$	$16\frac{1}{4}$	50	6 "
F	4500	215	15	$13\frac{3}{8}$	$10\frac{3}{4}$	$3\frac{1}{4}$	$18\frac{1}{4}$	$9\frac{1}{8}$	$19\frac{7}{8}$	90	$7\frac{1}{2}$ "
F	7500	315	15	$13\frac{3}{8}$	$16\frac{1}{2}$	$3\frac{1}{4}$	$23\frac{7}{8}$	$9\frac{1}{8}$	$25\frac{1}{4}$	150	9 "

The primary fuse box generally employed with the type "F," General Electric Company's transformers, is shown in Fig. 234.

The type "F" transformers of the General Electric Company have been in a great measure superseded by a more recent type H, which embodies the latest improvements in regulation and efficiency.

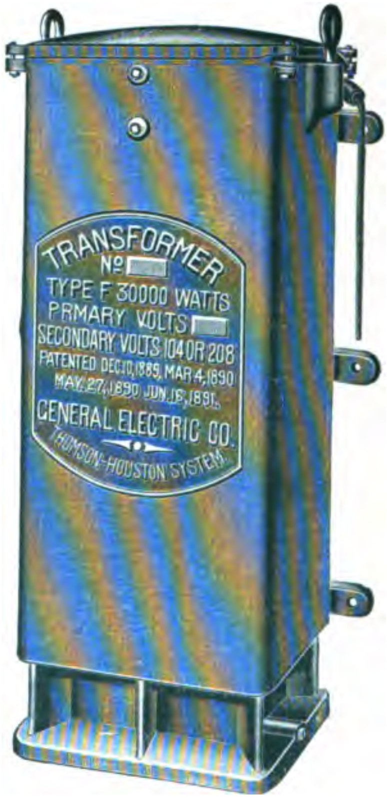

TRANSFORMER
Nº
TYPE F 30000 WATTS
PRIMARY VOLTS
SECONDARY VOLTS 104 OR 208
PATENTED DEC. 10, 1889, MAR. 4, 1890
MAY 27, 1890 JUN. 16, 1891.
GENERAL ELECTRIC CO.
THOMSON-HOUSTON SYSTEM.

Fig. 232—"General Electric" 30,000 Watts Type F, A. C. Transformer.

Fig. 235, shows the construction of the General Electric Company's type "H," 1,000-watt transformer. In this transformer there are two vertical cores of rectangular cross-section as shown at C. These are wound first with the secondary coil *SS*, and then with the primary coil pp. The two wound cores are then set up side by side, and connected together magnetically by a number of soft steel strips interleaved with the sheets forming the core. By this means a closed magnetic

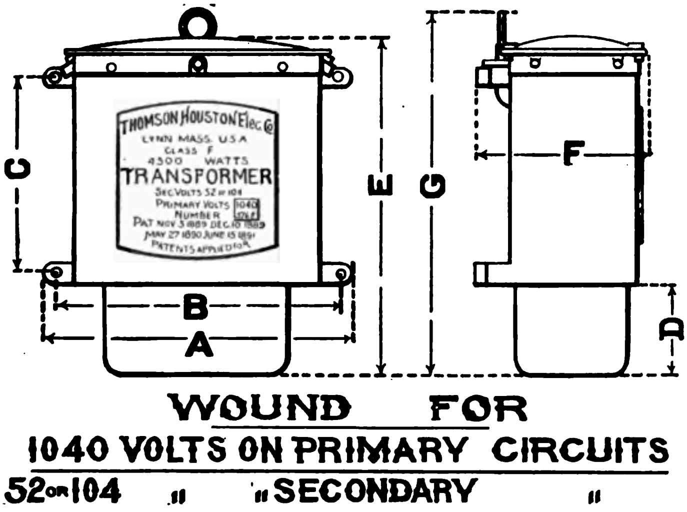


Fig. 233—Dimensions of "General Electric" Type F Transformers.

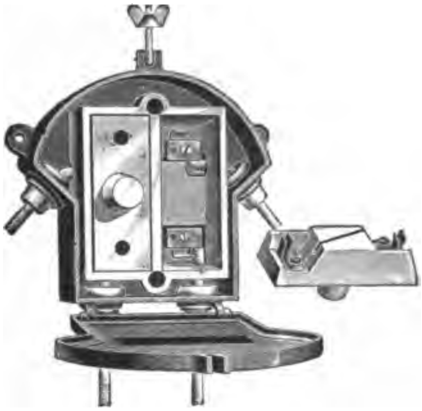


Fig. 234—"General Electric" Primary Fuse-Box of Type F Transformer.

circuit is formed. The two primary coils are connected in series and their terminals brought out at P, P. The secondary coils are connected in parallel, or in series, according to the pressure required. These transformers are usually wound for a frequency of 60 cycles, a primary pressure of 2,000 volts, and a secondary pressure of either 115 or 230 volts.

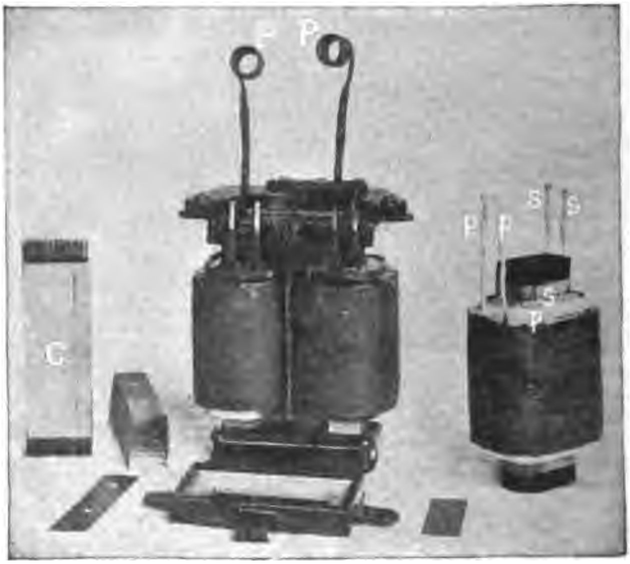


Fig. 235—"General Electric" Type H Transformer.

Fig. 236, shows a 1,000-watt, type "H," transformer and its case. These transformers are kept submerged in oil.

Fig. 237, shows a General Electric Company's 15-K.W., 60-cycle, type "H," transformer and its case. Here, the two vertical cores, with their primary and secondary windings, are clearly visible. Cylinders of slit sheet copper, called "ground-shields," like that shown at Y, are placed between the primary and secondary windings, and the wires w, attached to them, are brought out at W, and grounded, so that there can be no accidental contact between high-pressure and low-pressure

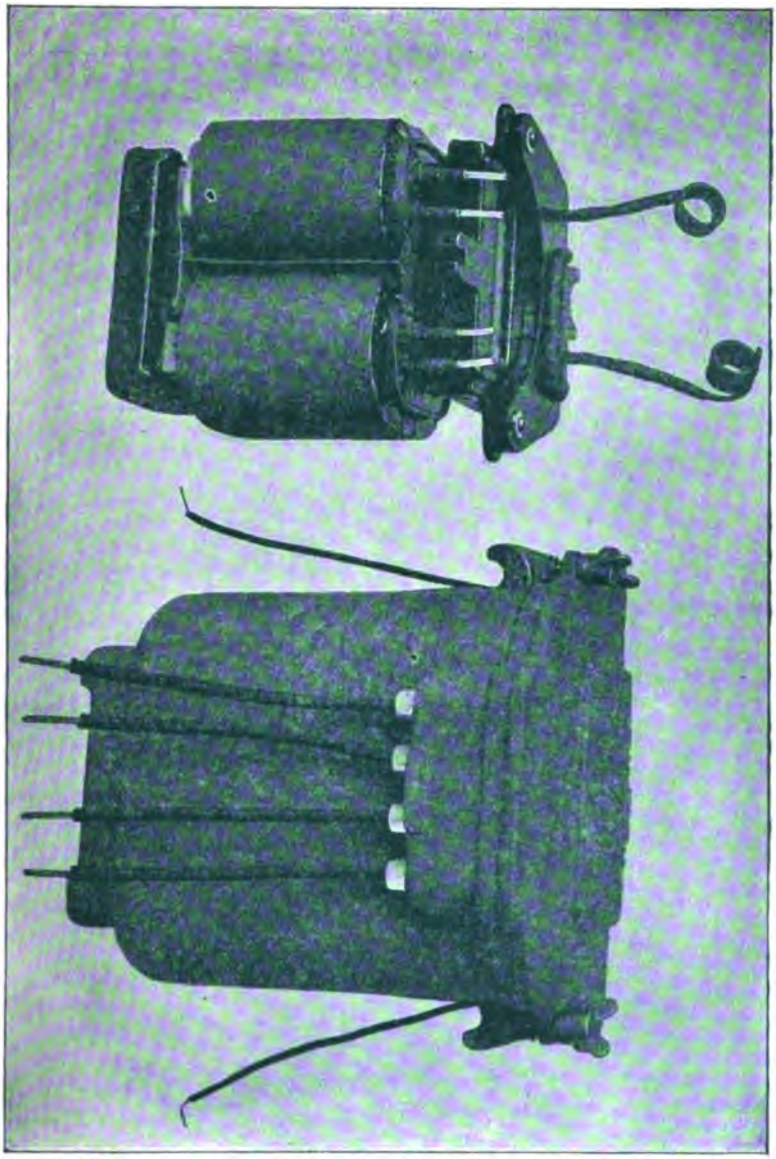


Fig. 236—"General Electric" Type H 60-Cycle Transformer.

circuits in the transformer. This transformer is wound for 2080 volts in the primary circuit, and for either 104 or 208 volts in the secondary circuit.

The type "H" transformer has been so designed as to possess a high efficiency at low frequency and light load.

Fig. 238, shows the General Electric Company's standard water-type transformer of the "H" pattern of 10-K.W. capacity

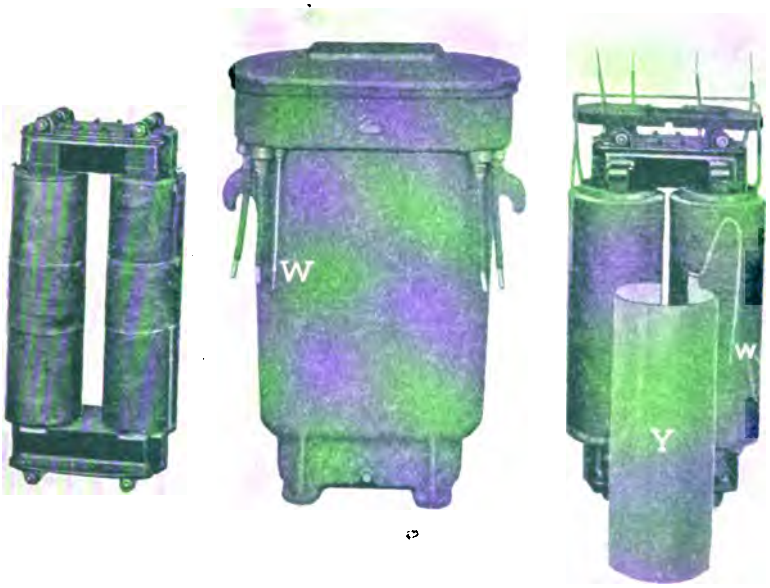


Fig. 237—"General Electric" 15-K. W. Type "H," A. C. Transformer.

wound for 2,000 volts in the primary circuit, and either 115 or 230 volts in the secondary circuit, at 60 cycles. All the leads are lead covered, and pass through the case into the transformer through brass stuffing boxes. The transformer is designed for use in manholes or subways, and may be operated under water, provided that the small iron pipe P, which ventilates the case, be carried high enough to pass above the water-line.

A 50-K.W. General Electric Company's type "H" transformer, of the air-cooled pattern, is shown in Fig. 239. Here, there are two upright cores of iron as before, linked together magnetically by laminated yokes above and below, which are clamped securely by covers and rods. The secondary winding is next to the core, and the primary winding on the outside. The two-foot rule, in front of the apparatus, shows that its total height is about four feet. A cylindrical shell of micanite separates the primary and secondary coils, and projects about two inches above and below them. These transformer coils are tested for insulation from the core and from each other, with a pressure of 30,000 volts. The primary is wound for 10,000 volts, and the secondary for 125.

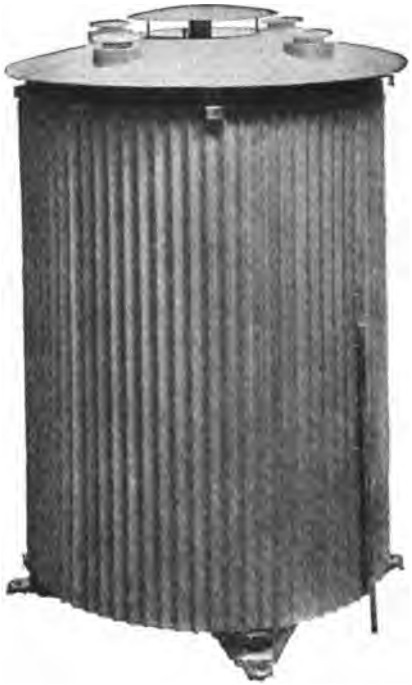


Fig. 240—Case of "General Electric" Air-Cooled Transformer.

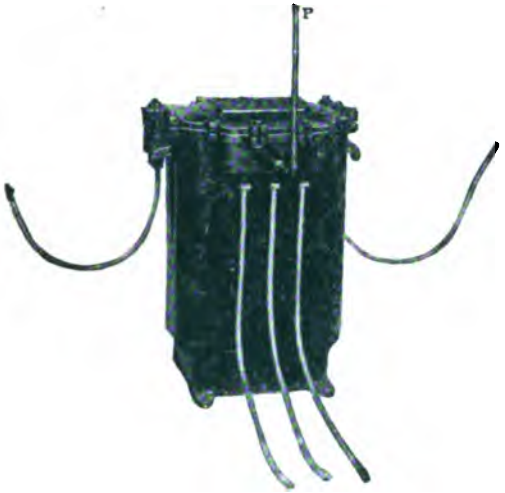


Fig. 283—" General Electric " Standard Water-Type Transformer.

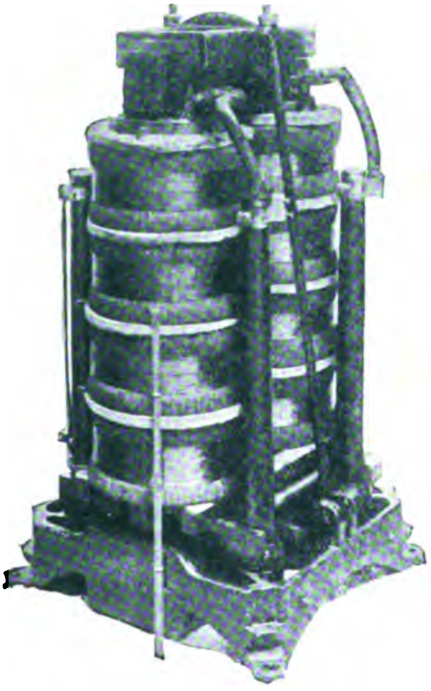


Fig. 239—50-K. W. " General Electric " Type H, High Tension Air-Cooled Transformer.

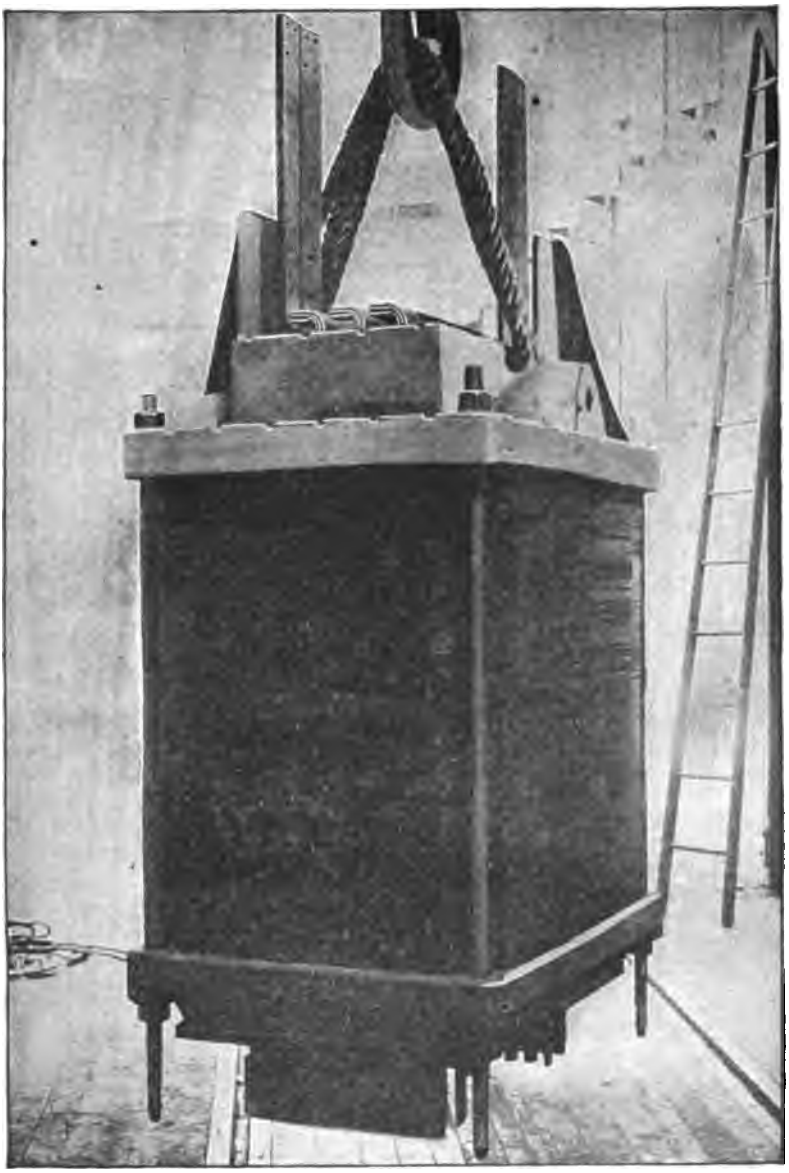


Fig. 242—Internal Construction of "General Electric" 750-K. W. A. C. Transformer.

Fig. 240, shows the external case provided for this transformer, with its ventilator and apertures for the leads.

Fig. 241, shows the General Electric Company's 750-K.W. (1,000 H. P.) transformer, constructed for the Carbide Manufacturing Company at Niagara Falls, and which reduces the pressure from 2,200 volts to 110 volts. This transformer is cooled by the use of oil, which, after circulating through it, is then carried through a cooling tank, inside of which are coils of piping carrying cold water. The circulation is effected by an electrically operated pump.

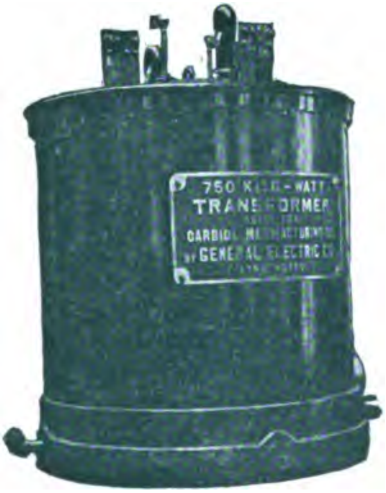


Fig. 241—"General Electric" 750-K. W. Transformer.

Fig. 242, shows the internal construction of this transformer.

An air-cooled transformer of the General Electric Company's 100-K.W. sub-station type, is shown in Fig. 243. Here the laminated iron core CC, is shown with the laminations passing transversely, and the coils L, L, wound longitudinally. T, T, are the secondary terminals. Such a transformer is suitable for a sub-station and for local distribution at reduced pressure, supplied by a main station at a considerable distance.

Fig. 244, shows three General Electric Company's air-cooled 265 K.W. transformers, situated in the Street Railway Power House at Buffalo, N.Y., and designed to reduce the 25-cycle triphase current received from Niagara Falls, at either 11,000 volts or 22,000 volts, to 365 volts, for delivery to a rotary-transformer and transformation to continuous current, suitable for operating the Buffalo Street Railway. The high-pressure current comes in at the left-hand side, and after passing through the fuses, enters the transformer primaries.

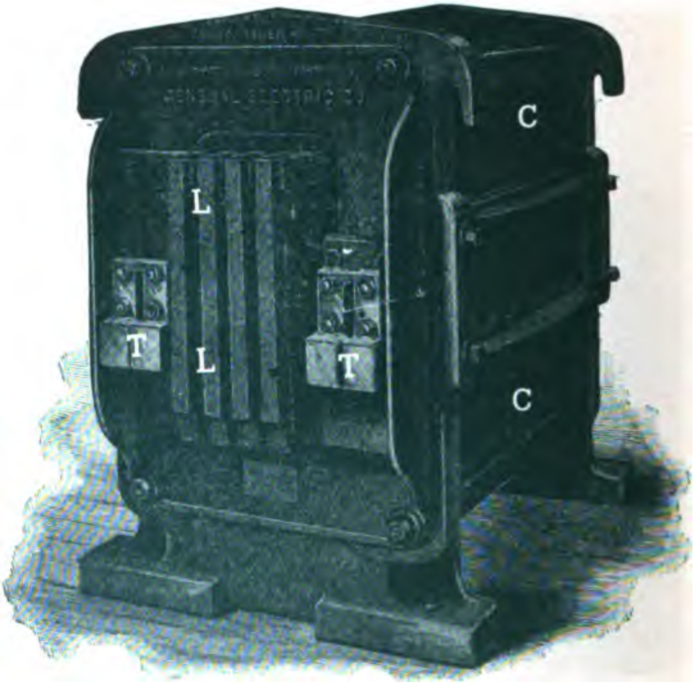


Fig. 243—"General Electric" Sub-Station Air-Blast Transformer.

The type "H" transformer has been designed to have as good a regulation and as small an iron-core loss as possible.

Since the sole purpose of a transformer is the transformation of electric power from a high pressure to a low pressure, or the reverse, the commercial value of such apparatus, apart from the question of its first cost and length of life or permanence, is found in the degree of perfection with which it effects such transformation. A perfect transformer would be one which could effect this transformation of power without any loss in the process. This, however, is clearly not realizable in practice, since an electric current in passing through any coil must inevitably lose some of its energy as heat. In addition to this, however, when an electric conductor is subjected to variations in the quantity of magnetism which passes through it, electric eddy currents are set up in it, which cannot be utilized, and which, therefore, uselessly waste some power. This ***eddy-current loss*** occurs both in the iron core plates and in the copper coils. It is to reduce these eddy-current losses to a commercial minimum that the iron core is laminated. The laminations are made in the direction in which the magnetism or magnetic flux passes through the core.

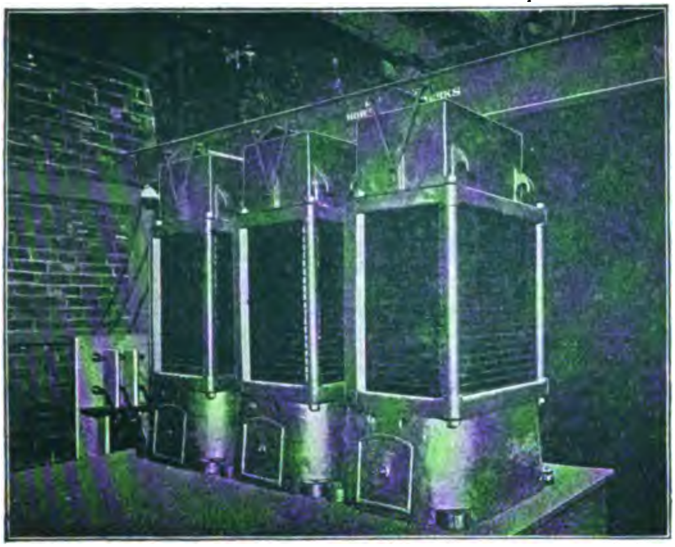


Fig. 244—Three "General Electric" Air-Cooled 265-K. W. Transformers.

The accompanying table gives the weights and efficiencies of different sizes of the type "H" transformer.

General Electric Type H 60-Cycle Transformers.—Data Table.

Watts. Capacity.	Iron Core Loss 60 Cycles.	Iron Core Loss 125 Cycles.	Regulation 60 Cycles Per Cent. Drop.	Regulation 125 Cycles Per Cent. Drop.	Efficiency Full Load 60 Cycles.	Efficiency Full Load 125 Cycles.	Net Weight. Pounds.
600	23	18	2.8	2.9	93.6	94.1	80
1000	30	23	2.59	2.7	94.6	95.2	100
1500	35	27	2.45	2.62	95.3	95.9	135
2000	45	34	2.3	2.5	95.7	96.2	170
2500	48	37	2.1	2.45	96.1	96.6	205
3000	60	46	2.1	2.45	96.3	96.6	225
4000	68	52	2.	2.35	96.5	96.8	280
5000	76	58	2.	2.44	96.5	96.9	330
6000	93	71	1.8	2.	96.6	96.9	445
7500	116	88	1.7	1.9	96.7	97.1	565
10000	155	117	1.44	1.61	97.1	97.5	695
15000	192	145	1.35	1.40	97.5	97.7	1025
20000	254	192	1.32	1.35	97.6	97.9	1250
25000	310	238	1.3	1.3	97.7	98.	1525
30000	360	272	1.3	1.3	97.8	98.1	1825

After a run of eight hours, at full load, the rise in temperature of the oil will not exceed 45 degrees Centigrade.

The most serious loss of power found in a transformer, however, arises from the continual reversal of magnetism which goes on in the iron core. Since even a comparatively low frequency of 60 cycles per second represents 120 reversals of magnetism taking place in the iron core of a transformer during each second of time; or 7,200 reversals of magnetism per minute; or, 10,368,000 per day, it is evident that in the course of a year, a very great number of magnetic reversals in the iron core will have taken place, and in most alternating-current systems the transformers are in operation for the entire 24 hours in the day. A very small but appreciable amount of energy is expended in every cubic inch of iron each time its magnetism is reversed. The amount expended depends both upon the quality of the iron, and upon the intensity of the magnetization. The softest irons are, generally speaking, those which require the expenditure of the least energy to reverse their magnetism, and the hardest irons and steels those, which require the expenditure of greatest energy. But it is not always true that the softest iron mechanically is the softest magnetically, and in order to reduce this magnetic loss of energy, great care is necessary in the selection of the quality of iron employed for transformer cores. Great improvements have been made in recent years in the magnetic quality of iron employed for transformers. The magnetic loss of energy increases with the magnetization in more than direct proportion; doubling the intensity or the maximum amount of magnetism per square inch of cross-section at each reversal, being attended by approximately a trebled increase of magnetic energy expended at each reversal.

Where transformers have to be excited from the primary mains 24 hours a day, they may be only actively employed in lighting for about three hours per day on the average, and the amount of energy expended during a year for the excitation of the transformers in magnetic loss, or loss by *hysteresis*, as it is called, may amount to a comparatively large fraction of the total amount of energy usefully delivered and sold to the consumer. The efficiency of a transformer, at a given load, is the ratio of the power usefully delivered to the consumer to the power taken by the transformer from its primary mains. But by the *all-day efficiency* of a transformer is meant the ratio of the amount of energy usefully delivered to the consumer, and which the consumer pays for, to the amount of energy taken by the transformer during the entire day from the primary circuit, and which energy the central station has to pay for in the coal consumed, attendance, interest, and depreciation. It is quite possible that a transformer may have a high efficiency at full load and, therefore, expend comparatively little power at full load, and yet, by reason of a comparatively low efficiency at small load, or a large expenditure of power in hysteresis, may have a small all-day efficiency and, therefore, be an expensive transformer from the point of view of the central-station manager. Of recent years, attention has been particularly directed to improvement in the all-day efficiency of transformers, and this has been accomplished by reducing the loss by hysteresis, through a better selection of iron and a more careful design in regard to magnetization.

It has also been found that the loss of power in the iron core due to hysteresis, tends to increase for a time after the transformer is first put into operation. This is alluded to as the ageing of the transformer, and is considered to be due to the continued magnetic reversals of magnetism under the influence of the increased temperature of the iron core under load. Owing to this ageiug of the core, the core loss in some transformers has doubled the original value when the transformer was originally installed. For this reason, transformer iron is selected not only with regard to its low hysteretic loss, but also with regard to its freedom from increase in that loss under continued service.

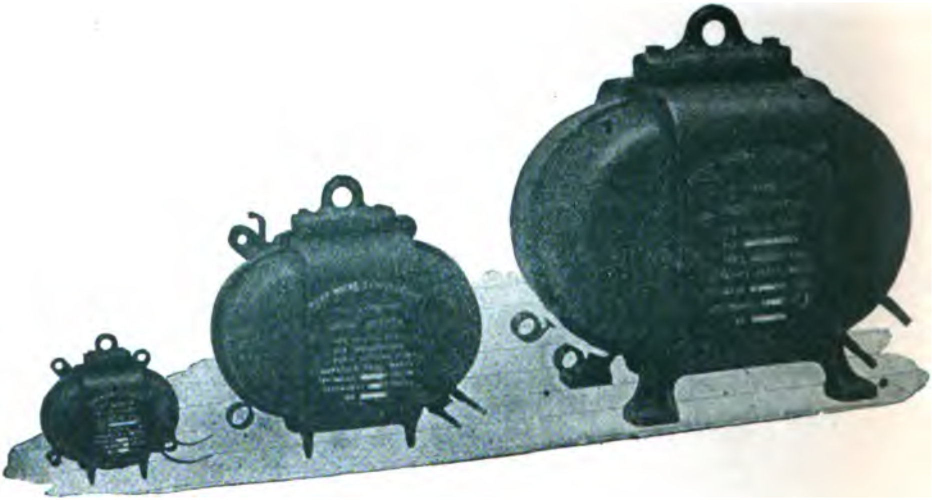


Fig. 245—"Wood" Transformers for 6, 100 and 500 Lights.

Fig. 245, shows three of the Fort Wayne Electric Corporation's "Wood" transformers for 6, 100, and 500 lights respectively. The internal construction of these transformers is shown in Fig. 246. Here, a pair of coils C, C, made up as one mass, has a core R R, built up of laminated sheets, and forming a closed magnetic circuit in two branches. The primary wires are brought out at *p*, *p*, and the secondary wires at *s*, *s*.

A 37.5-K.W., or 750-light sub-station, "Wood" transformer, is shown in Fig. 247. These transformers are wound for frequencies of from 60 to 140 cycles per second. Their primaries are usually wound for 1,000 or 2,000 volts and their secondaries for 100 or 200 volts.

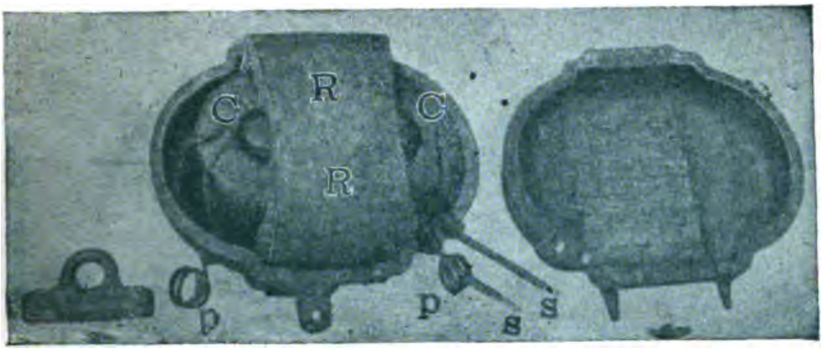


Fig. 246—Interior of "Wood" Transformers.

The data relating to these transformers is given in the accompanying table. It will be seen that the 37.5-K.W. transformer is stated to have a full-load efficiency of 98.33%, a drop of pressure of 2.2%, a magnetizing current of 0.382 ampere, a loss of power on open circuit of 244 watts, and a total weight complete of 1,860 pounds.

A Wood arc-light transformer of 450 watts capacity is represented in Fig. 248. This is wound for any desired frequency with a primary of 1,000 volts pressure.

Fig. 249, shows the Royal Electric Company's type of transformer, which is constructed in standard sizes from 500

List of Standard Sizes and Data of "Wood" Transformers.

Capacity in	Watts	300	600	1,250	2,500	3,750	5,000	6,250	12,500	18,750	25,000	37,500
	Lights, 16 C. P.	6	12	25	50	75	100	125	250	375	500	750
Per cent. Efficiency at	Full Load	91.41	93.89	95.05	96.08	96.52	97.01	97.06	97.55	97.89	98.04	98.33
	¾ Load	82.79	93.01	94.42	95.78	96.25	96.86	96.96	97.53	97.93	98.19	98.39
	½ "	86.35	90.86	92.77	94.86	95.30	96.25	96.41	97.31	97.75	97.82	98.33
	¼ "	76.85	84.30	87.49	91.18	92.11	93.76	94.09	95.78	96.41	96.76	97.30
	⅛ "	......	73.25	78.17	84.25	85.81	88.69	89.23	92.40	93.51	94.14	95.09
	1/16 "	......	......	64.30	72.96	75.31	79.85	80.41	85.75	87.99	89.11	90.82
Volts Drop at Full Load.	50 Volts, Secondary	1	1	1	1	1	1	1	1	......	......	.....
	100 Volts, Secondary	2	2	2	2	2	2	2	2	2	2.2	2.2
Magnetizing Current		0.031	0.036	0.056	0.078	0.104	0.109	0.124	0.181	0.255	0.279	0.382
Watts loss on Open Secondary		22	27	43	57	76	78	92	125	158	189	244
Weight, complete, lbs		31	51	98	153	205	283	355	650	933	1,175	1,860

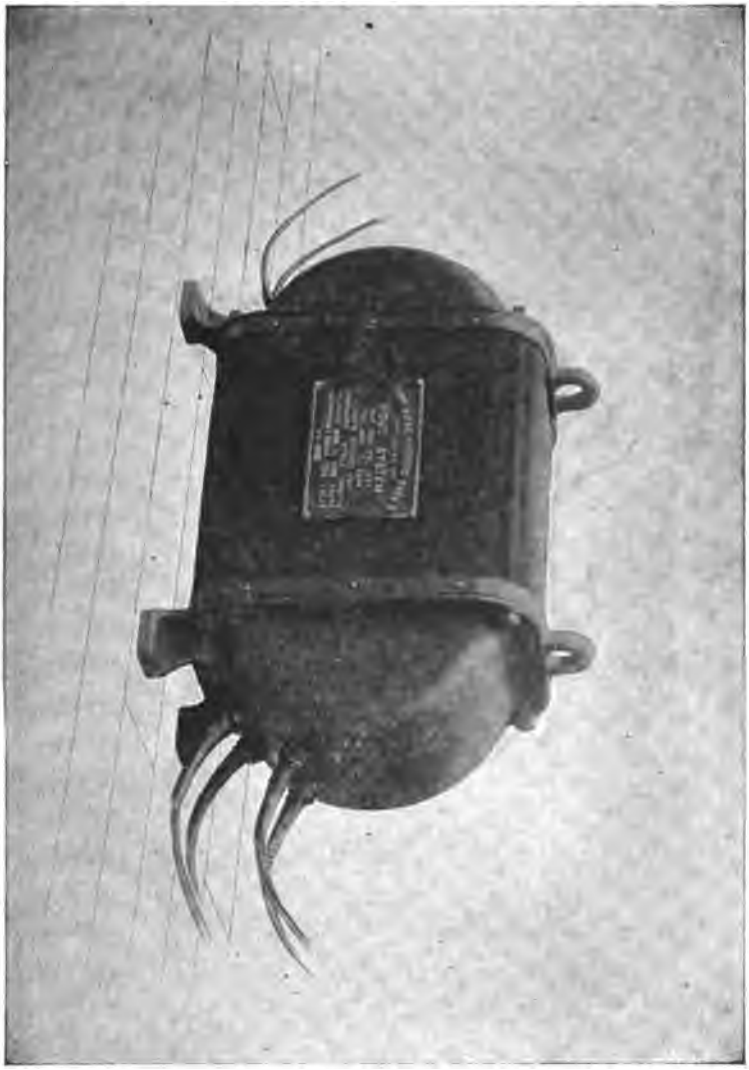


Fig. 247—750 Light Sub-Station "Wood" Transformer.

watts to 25-K.W. capacity, either for 2,000 or 1,000 volts primary pressure, and 50 or 100 volts secondary pressure. Near the bottom of the case, are two hemispherical covers forming a single casting clamped tightly against the case by the thumb-screw. These protect a pair of primary fuse-blocks provided with insulating handles which extend from the front of the casing to the back.

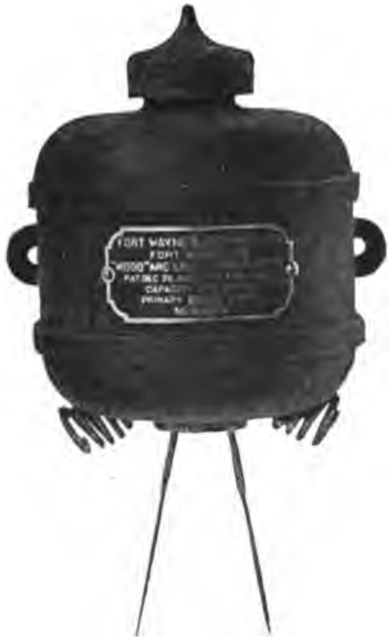


Fig. 248—"Wood" Arc-Light Transformer.

Fig. 250, shows the construction of the Diamond Electric Company's transformer. Here there are two primary and two secondary coils, one on each side of a rectangular laminated iron core frame. The interior coils are the secondary coils, and the exterior coils are the primary. The standard sizes of these transformers are given in the accompanying table.

Fig. 251, shows a Lakon Company's 1,500 watt transformer. The Wagner Electric Manufacturing Company's 10-light or 500-watt transformer, without its case, is shown in Fig. 252. Here, the laminated iron core, clamped together between end-plates by nuts and bolts, forms a magnetic cir-

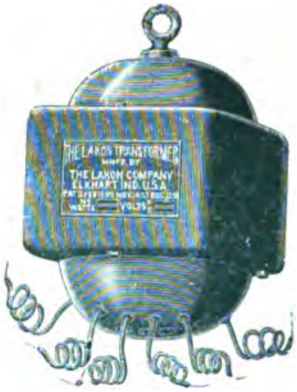


Fig. 251—"Lakon Company" 1500 Watts Transformer.

TABLE OF WEIGHTS OF DIAMOND COMPANY'S TRANSFORMERS.

16 C. P. LAMPS.	WATTS.	WEIGHTS.
10	500	49 lbs.
15	750	74 "
20	1,000	87 "
25	1,250	93 "
30	1,500	98 "
40	2,000	115 "
50	2,500	135 "
75	3,750	150 "
100	5,000	205 "
150	7,500	300 "
200	10,000	375 "
300	15,000	425 "
400	20,000	600 "
500	25,000	800 "

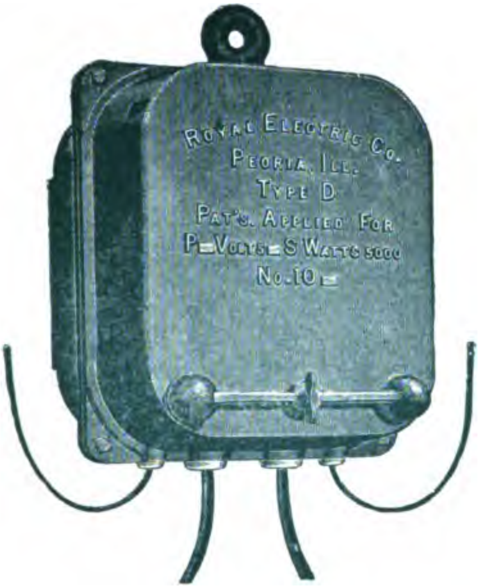


Fig. 249—"Royal Electric" Type S Transformer.

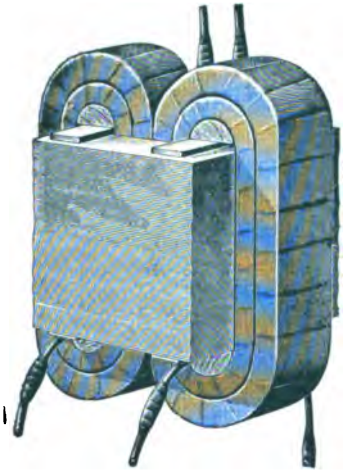


Fig. 250—"Diamond Electric" Transformer.

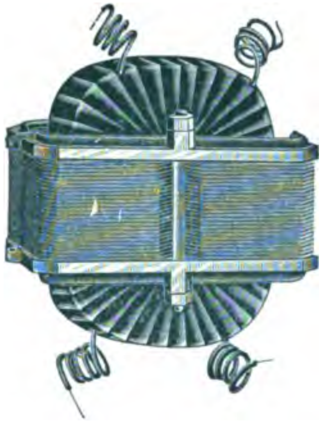


Fig. 252—“Wagner” 10 Light Transformer Without Box.

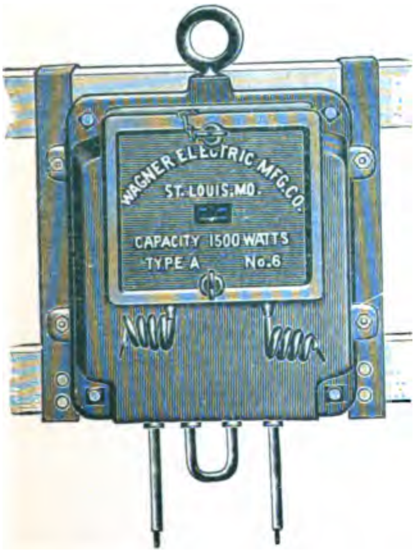
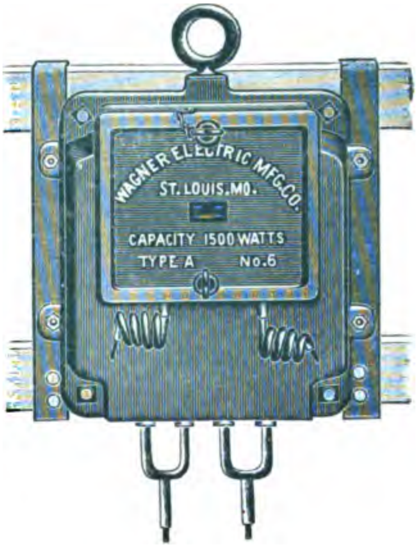

WAGNER ELECTRIC MFG.CO.
ST. LOUIS, MO.
CAPACITY 1500 WATTS
TYPE A No.6

Fig. 253—“Wagner” Transformer, 100 Volts.


WAGNER ELECTRIC MFG.CO.
ST. LOUIS, MO.
CAPACITY 1500 WATTS
TYPE A No.6

“Wagner” Transformer, 50 Volts.

cuit around the coils in two branches. Fig. 253, shows a 30-light, or 1,500-watt, transformer mounted for out-door work upon a pair of wooden beams. Two primary wires enter the fuse box on the face of the transformer, while four secondary wires emerge from beneath. These wires may be connected up either in series to deliver 100 volts, or in parallel to deliver 50 volts, as shown.

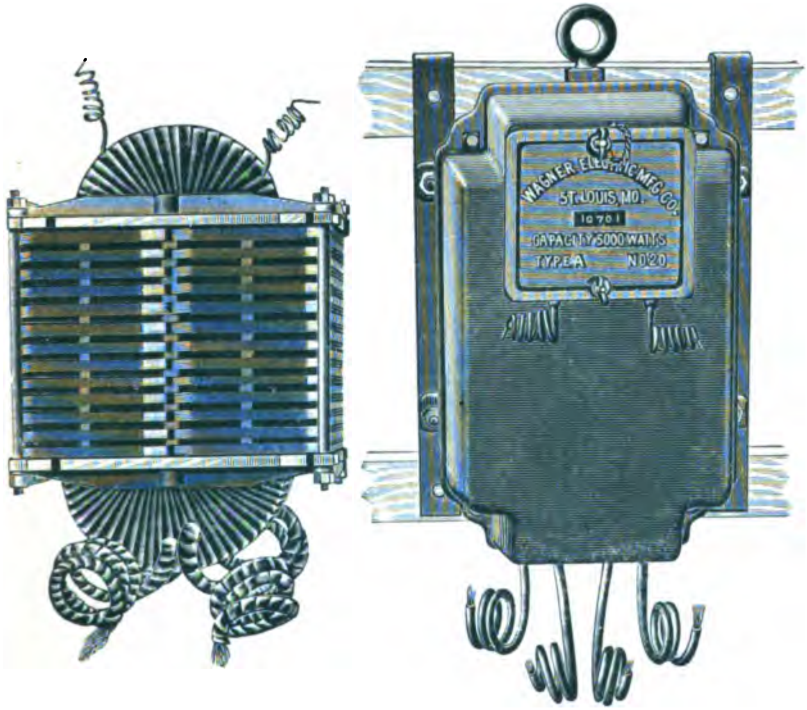


Fig. 254.

"Wagner" Transformer Without Case. **"Wagner" Transformer With Case.**

A 100-light or 5,000-watt Wagner transformer and its case, are shown in Fig. 254. Here, the iron core is assembled in a somewhat different manner, so as to provide a greater surface for ventilation.

Fig. 255, shows a 150-light or 7,500-watt oil-cooled transformer, in its case and mounted for out-door service. This is the largest standard size used for out-door work. A 500-light air-cooled transformer for in-door installation is shown in Fig. 256. Here, the primary wires enter the case on the left-hand side, and the secondary wires emerge on the right-hand side.

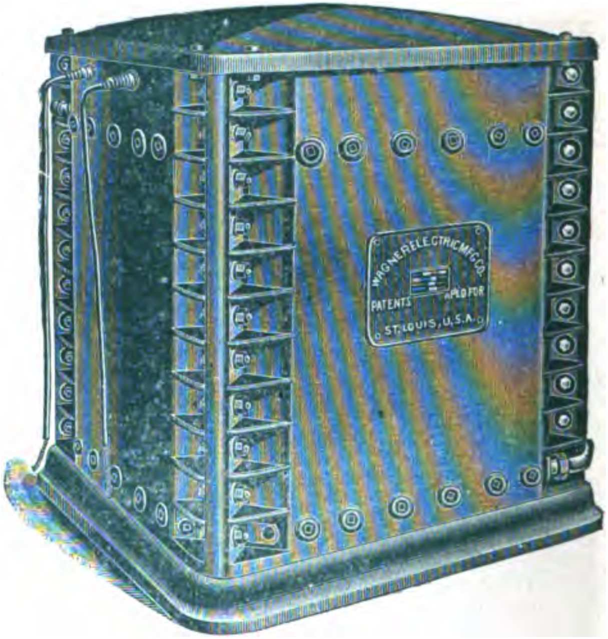


Fig. 257—" Wagner " 100-K. W. Water-Jacketed Transformer.

Fig. 257, shows a Wagner oil-cooled step-up transformer for 2,000 lights, or 100 K.W. capacity. A Wagner "economy coil," or choking coil, employed to reduce the secondary 50 or 100-volt pressure to that required for the operation of one or more arc lamps, is shown in Fig. 258.

The accompanying table shows the weights, sizes and regulation of the standard type "C," Wagner transformers.

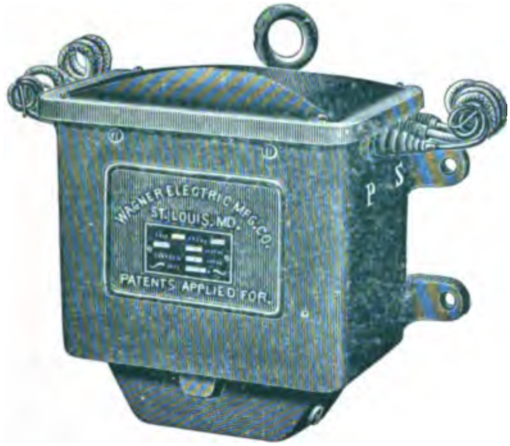

WAGNER ELECTRIC MFG. CO.
ST. LOUIS, MO.
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Fig. 255—" Wagner" 150-Light Type D Transformer.

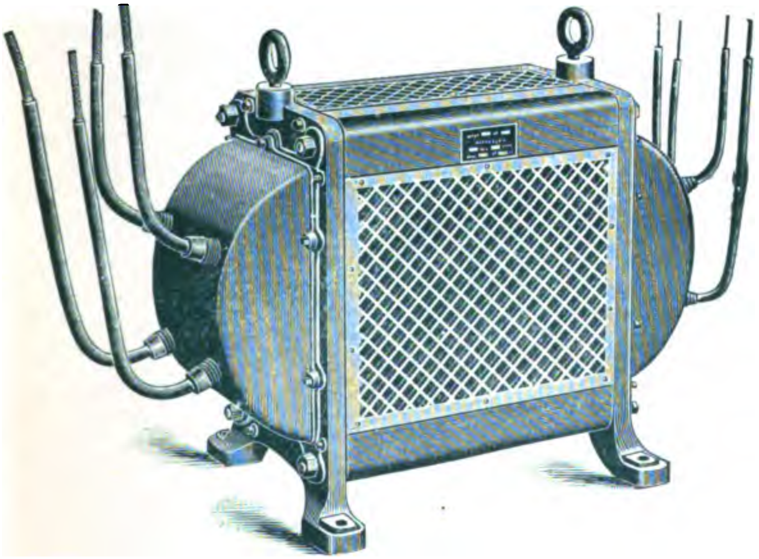


Fig. 256—" Wagner" 500-Light Transformer.

SIZES, TYPE C, WAGNER COMPANY'S STANDARD TRANSFORMERS.

Number.	Capacity, Lights.	Capacity, Watts.	Regulation.	Approximate Weight.
1	5	250	2½ p. c.	40 lbs.
2	10	500	2½ p. c.	55 lbs.
4	20	1,000	2½ p. c.	80 lbs.
6	30	1,500	2¼ p. c.	105 lbs.
8	40	2,000	2¼ p. c.	130 lbs.
12	60	3,000	2¼ p. c.	170 lbs.
16	80	4,000	2¼ p. c.	230 lbs.
20	100	5,000	2 p. c.	280 lbs.
25	125	6,250	1.8 p. c.	340 lbs.
30	150	7,500	1.8 p. c.	390 lbs.
50	250	12,500	1.6 p. c.	600 lbs.
100	500	25,000	1.5 p. c.	900 lbs.

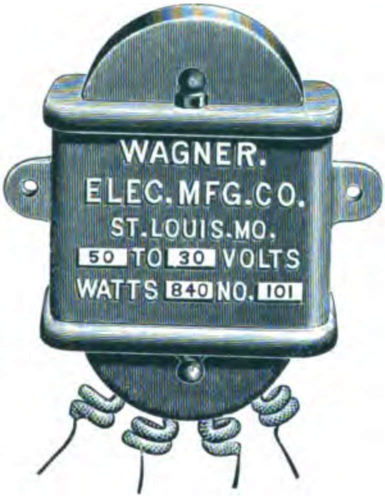


Fig. 258—"Wagner" Standard Arc-Light Transformer.

A similar line of Wagner transformers are constructed, called type "B," which are lower in price, lighter in weight, and have a somewhat lower efficiency. These transformers are described in the following table.

A third type of Wagner transformers, called type "D," are constructed for a closer regulation and higher efficiency than type "C." These are given in the following table. They are heavier and somewhat higher in price. Fig. 259 shows a "Wagner" type "D" ornamental arc-light transformer.

Fig. 260, shows a "Packard" transformer, and Fig. 261, the "Boston" transformer. Both are arranged for either 50 volts or 100 volts secondary pressure.

LIST OF WAGNER TRANSFORMERS TYPE "B."

Size.	Capacity, Lights.	Capacity, Watts.	Approximate Weight,
I	5	250	30
II	10	500	45
IV	20	1,000	60
VI	30	1,500	80
VIII	40	2,000	110
XII	60	3,000	140
XVI	80	4,000	180
XX	100	5,000	230
XXX	150	7,500	340
XL	200	10,000	420

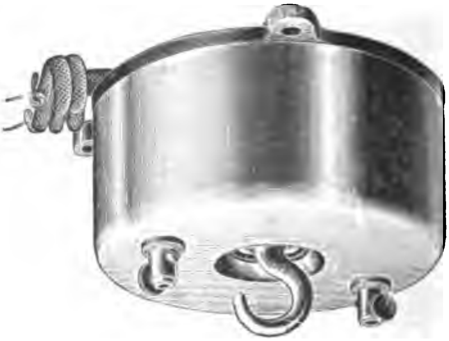


Fig. 259—"Wagner" Ornamental Arc-Light Transformer.

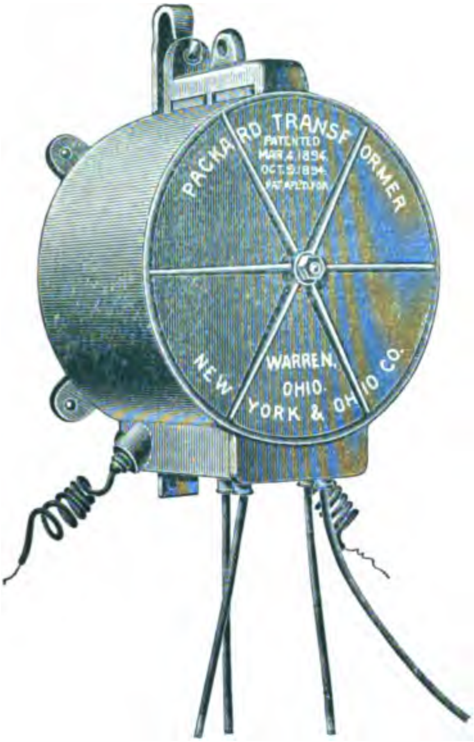

PACKARD TRANSFORMER
PATENTED MAR 4 1894 OCT 9 1894 PAT APL'D FOR
WARREN, OHIO.
NEW YORK & OHIO CO.

Fig. 260—" Packard " Transformer.

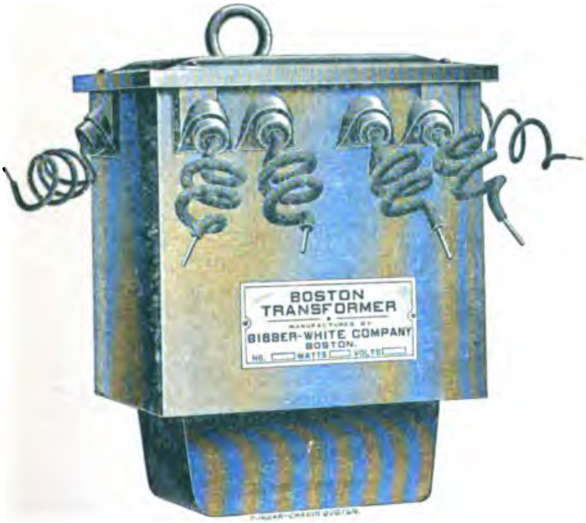


Fig. 261.—" Boston Transformer.

TYPE "D" WAGNER TRANSFORMERS.

Number.	Capacity, Lights.	Capacity, Watts.	Regulation.	Approximate Shipping Weight.
2	10	500	2½ p. c.	87 lbs.
4	20	1,000	2.4 p. c.	107 lbs.
6	30	1,500	2.85 p. c.	131 lbs.
8	40	2,000	2 p. c.	147 lbs.
12	60	3,000	2 p. c.	175 lbs,
16	80	4,000	2 p. c.	275 lbs.
20	100	5.000	2 p. c.	345 lbs.
25	125	6,250	2 p. c.	416 lbs.
39	150	7,500	2 p. c.	660 lbs.
40	200	10,000	2 p. c.	725 lbs.
60	300	15,000	1.85 p. c.	800 lbs.
80	400	20,000	1.85 p. c.	1,000 lbs.
100	500	25,000	1.75 p. c.	1,250 lbs.
120	600	30,000	1.75 p. c.	1,400 lbs.
200	1,000	50,000	1. p. c.	2,000 lbs.

CHAPTER X.

CONTINUOUS-CURRENT MOTORS.

PRACTICALLY, any continuous-current dynamo, when suitably traversed by an electric current, will operate as a motor and transform electric power into mechanical power, or reverse its function as a dynamo. Consequently, any of the generators, which have been considered in the chapters on continuous-current dynamos, may be regarded as continuous-current motors. There are, however, certain differences between the connections and accessories of a machine when employed as a generator, and employed as a motor. Thus, when a machine is used as a generator, it is first driven up to speed and allowed to excite itself to the right pressure, and is then connected to its circuit. In a motor, the machine has to be connected to the circuit before it will start, and it must not be so connected without first ensuring that the current strength which will pass through it when the connection is made, shall not be excessive. This usually necessitates the introduction of some auxiliary device, and in some cases some slight difference in the construction of the switchboard, or headboard, attached to the machine.

A standard bipolar motor, of the Western Electric Company, is shown in Fig. 262. T, T, are the main terminals of the machine, connected directly to the brushes through the wires W, W. t, is the field terminal. A diagram of the connections of these and other motors of the same type is shown in Fig. 263. Here T and T′, are the armature terminals, or the main terminals of the machine, connected directly to the brushes. f, is connected to one terminal of the shunt field, that is the exciting coil or coils on the field magnet or field

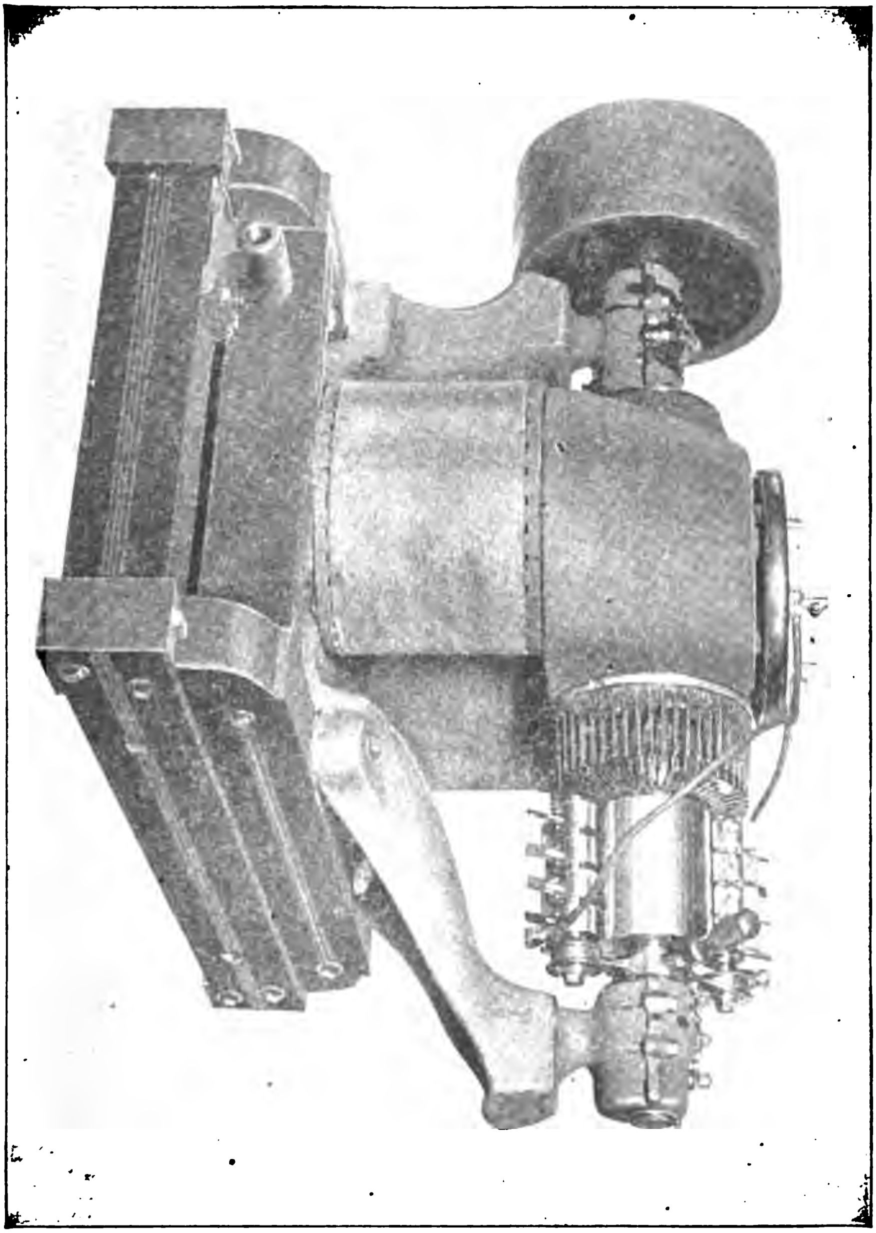


Fig. 202—"Western Electric" Bipolar Motor.

magnets, which coil is connected across the mains, or in shunt to the armature. Motors employing a shunt field are called *shunt motors.* Nearly all large motors operated from incandescent lighting, or power circuits, are shunt motors. Such motors have a comparatively uniform speed of rotation under varying loads. The other terminal of the shunt field is connected to T, so that when in operation, f, is connected to T′, and both are connected to one main, say the negative, while T, is connected to the other or positive main.

When starting a shunt motor, it is always necessary to close the field circuit before closing the armature circuit. That is to say, the field magnets must be magnetized before any current is allowed to flow through the armature. This is done by connecting the wires T and f, with the + and — mains respectively. If, under these circumstances, the remaining connection between T′, and the negative main were made directly, a very powerful current would tend to rush through the armature, which has a comparatively low resistance.

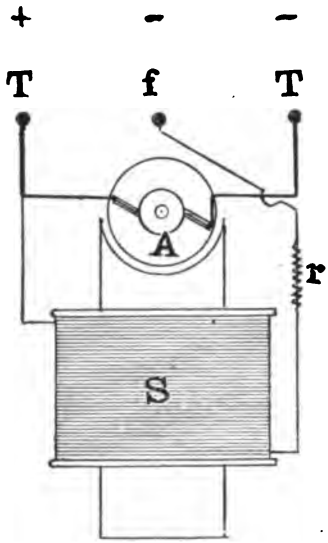


Fig. 263—Diagram of Connections of a Shunt-Wound Motor.

This current might not only be so powerful as to endanger the machine, but the mechanical impulse it would communicate would be so violent that the starting effort might damage the armature. It is necessary, therefore, to insert a suitable resistance into the armature circuit of the motor, so as to restrict the flow of current at the outset. After the motor has started, this *starting resistance* in the armature circuit is reduced, and when full speed has been attained, the resistance is withdrawn entirely; for, while running, the motor produces a *back pressure* or voltage, which checks the current and restricts its amount to that required to operate the mechanical load on the machine. This back pressure is commonly called *counter electromotive force.* In the figure, the resistance r, in the shunt-field circuit controls, within certain limits, the field exciting current, and the speed of the motor.

The connections of an ordinary shunt motor with a pair of electric mains is shown in Fig. 264. It will be seen that the mains MM, M′M′, are connected to the motor by a pair of branches b, b′, taken from the branch cut-out, through a pair of safety fuses f, f′, which are designed to melt and interrupt the motor circuit should the current through the motor become excessive. A double-pole switch is then inserted so as to connect or disconnect both sides of the circuit with the motor. The terminal B, is the field terminal, while terminals A and C, are the armature terminals. As soon as the double-pole switch S, is closed, the current flows through the field coils by the terminals A and B, the circuit connections being indicated by the dotted lines on the board. The starting box handle is then slowly turned to the left. This connects the terminals B and C, through the resistances of the rheostat R, thus causing the armature to start. As the motor accelerates, the handle of the starting box is gradually turned until finally the resistance in the box is entirely cut out, and the motor runs with the armature directly connected across the mains.

A form of resistance box or rheostat employed by the

Crocker-Wheeler Electric Company, in connection with their motors, is shown in Fig. 265. These rheostats may be employed in the armature circuit as starting boxes, or, in the shunt-field circuit as regulators, according to design. They

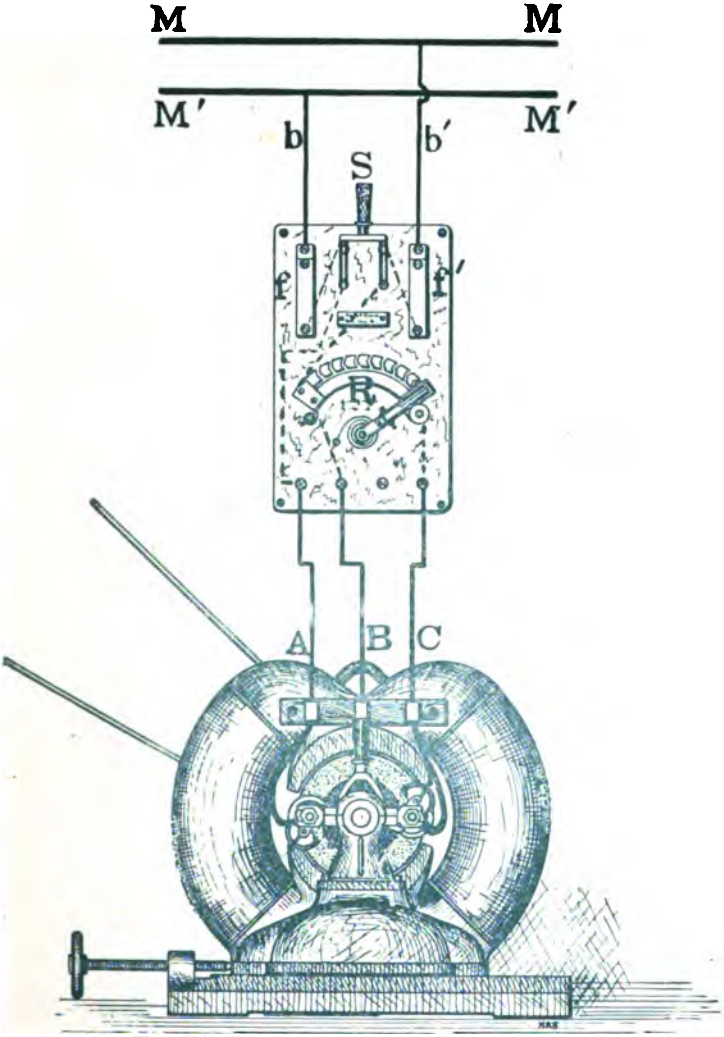


Fig. 264—Connections of an Ordinary Shunt Motor.

have a cast iron frame, with a top and bottom of slate. The resistance coils in the three largest sizes shown are made of iron wire, and are introduced into the circuit by the switch-handle which moves over the contact points on the slate cover. In the smallest size shown, the resistance coils are made of German silver wire wound upon steel tubes, and enveloped in enamel. No starting box is ordinarily required for motors of ½ H.-P. or less, the ¼ H.-P. and ½ H.-P. boxes shown in the figure being employed as field regulators only. Larger motors require starting boxes of a size depending on the power of the motor.

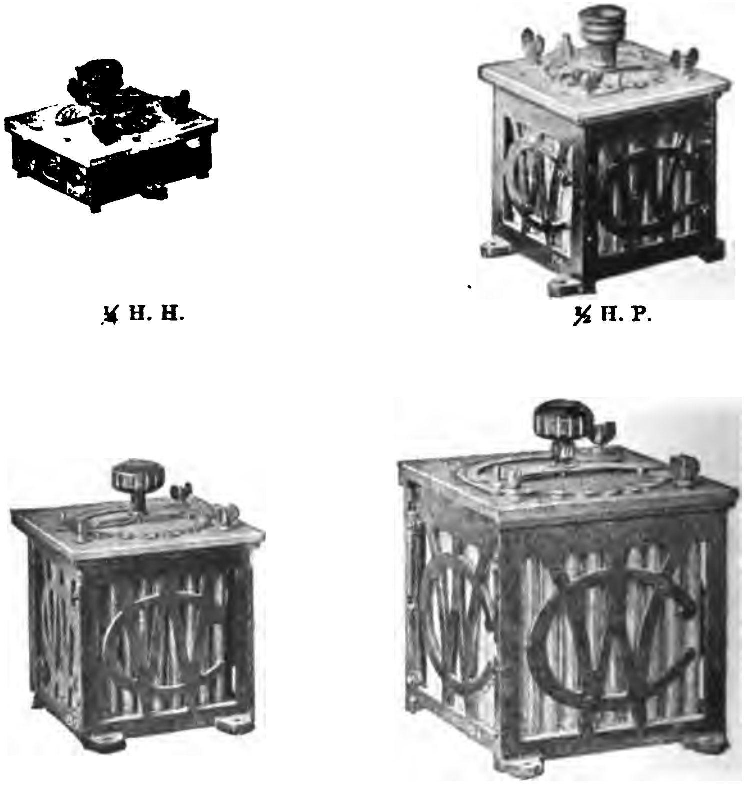

¼ H. H.
½ H. P.
1 H. P.
5 H. P.

Fig. 265—Crocker-Wheeler Starting Rheostats.

Fig. 265 A, shows two sizes of Crocker-Wheeler cut-off box, suitable for 15 and 75 amperes respectively. These boxes

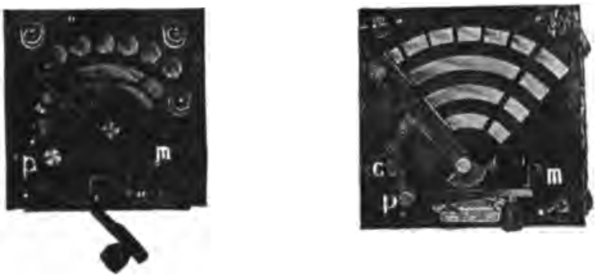


Fig. 265 A—" Crocker-Wheeler " Single-Pole " No Current Automatic Cut-Offs.

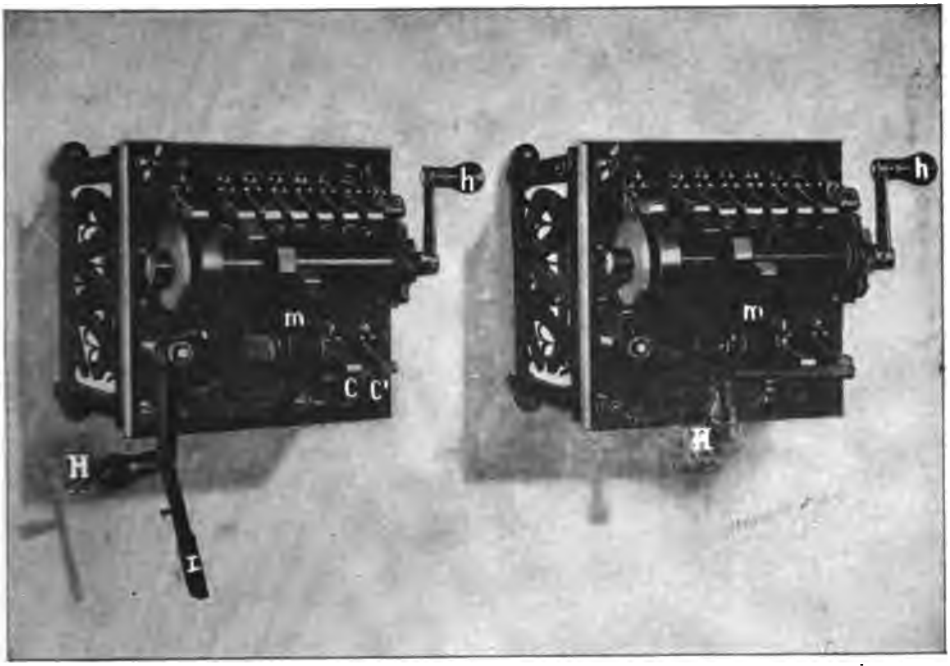


Fig. 265 B—" Crocker-Wheeler " 150 Ampere Cut-Off Starter.

are supported upon a wall near the motor and contain starting resistances. In these cut-off boxes the contact arm is moved by hand over the series of contacts on the cover. A secondary arm, movable about a pivot p, closes a main contact at c. It is supported when the motor is in operation, by the excitation of the electro-magnet m. Should the current fail at the mains, this magnet will automatically release its armature, thus breaking the secondary contact c, and allowing the arm to fall.

A larger cut-off starting box, suitable for 150 amperes is shown in Fig. 265 B. Here the handle h, closes the rheostat contacts in succession, while the electro-magnet m, attracting the armature H, closes the circuit c c′, through the ex-extremity x, of the secondary arm. Should the pressure fail at the mains, the circuit of the motor will be automatically broken by the falling of the secondary arm. All of these starters can be arranged to break the main circuit at overload as well as at total failure of current.

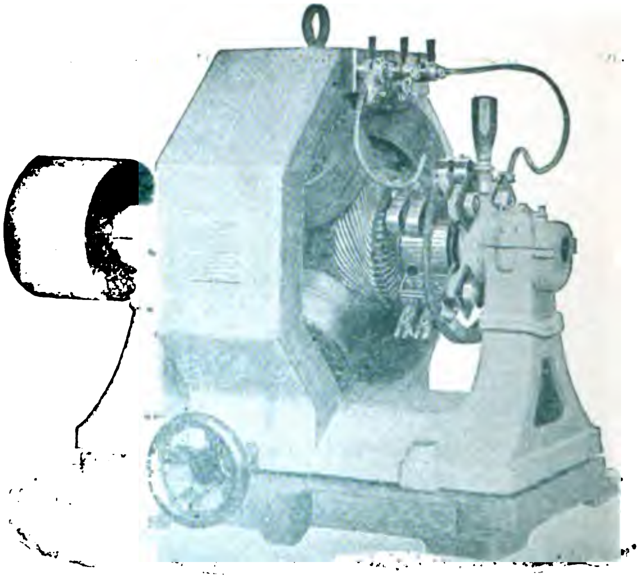


Fig. 266—"Western Electric" Multipolar Motor.

Fig. 266, shows a standard type of Western Electric Company's multipolar motor. These machines have four poles and four sets of brushes. The resistance of the field coils in this, as in all shunt motors, is so proportioned that the correct amount of current shall pass through the coils for their excitation when the correct pressure is maintained at the machine terminals ; i. e., when the terminals are connected to the mains of the supply system.

The accompanying table gives data of the Western Electric Company's multipolar motors. The Western Electric bipolars are of the same as that already described as generators on page 100 in connection with Fig. 62.

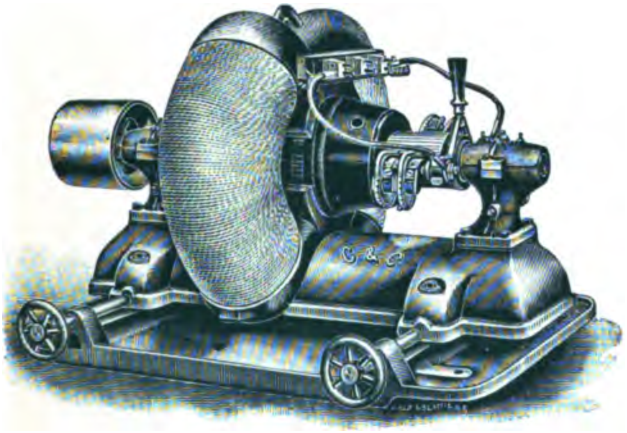


Fig. 267—" C. & C." Electric Motor.

Two types of "C and C," Electric Motor Company's bipolar motors, intended for incandescent lighting circuits, are shown in Figs. 267 and 268. The sizes of these motors are given in the accompanying table.

The general type of "C and C" quadripolar iron-clad motors, is shown in Figs. 269 and 270. The dimensions of these machines is shown in Fig. 271.

TABLE OF WESTERN ELECTRIC COMPANY'S SLOW SPEED MULTIPOLAR DYNAMOS.

KILOWATTS.	POLES.	HORSE POWER.	APPROXIMATE SPEED—FULL LOAD.	VOLTS.	AMPERES.	SHIPPING WEIGHT.	FLOOR SPACE PERPENDICULAR TO SHAFT.	FLOOR SPACE PARALLEL TO SHAFT.	HEIGHT FROM FLOOR TO CENTRE OF SHAFT.	TOTAL HEIGHT.	PULLEY—DIAMETER.	PULLEY—FACE.
							INCHES.	INCHES.	INCHES.	INCHES.	INCHES.	INCHES.
½	4	½	1500	110	5.5	220	15	18	8⅝	17	4	2¼
	"	"	1600	220	2.7	"	"	"	"	"	"	"
	"	"	1700	500	1.2	"	"	"	"	"	"	"
3	4	3	1000	110	26.5	670	23⅝	27½	13¼	24⅝	5¾	3½
	"	"	"	220	13.	"	"	"	"	"	"	"
	"	"	1075	500	5.5	"	"	"	"	"	"	"
5	4	5	900	110	42	1000	25¾	33	15¼	28	8	4
	"	"	"	220	21	"	"	"	"	"	"	"
	"	"	1000	500	9	"	"	"	"	"	"	"
9	4	10	800	110	85	1660	29¾	41⅞	17¾	34⅝	9	6½
	"	"	"	220	42	"	"	"	"	"	"	"
	"	"	875	500	18.5	"	"	"	"	"	"	"
12	4	15	625	110	121	2700	41	50	20¼	40½	12	7½
	"	"	"	220	59	"	"	"	"	"	"	"
	"	"	725	500	26	"	"	"	"	"	"	"
17	4	20	575	110	160	3075	53	52	19¼	39¼	15	9
	"	"	"	220	79	"	"	"	"	"	"	"
	"	"	650	500	35	"	"	"	"	"	"	"
20	4	25	550	110	200	3860	41	53¼	22½	45	16	9¼
	"	"	"	220	97.5	"	"	"	"	"	"	"
	"	"	600	500	43	"	"	"	"	"	"	"
30	4	35	425	110	275	6000	50	61½	26	52½	20	12¼
	"	"	"	220	134	"	"	"	"	"	"	"
	"	"	475	500	59	"	"	"	"	"	"	"
40	4	47	400	110	365	6650	50	63¼	26	52½	23	15
	"	"	"	220	181	"	"	"	"	"	"	"
	"	"	450	500	80	"	"	"	"	"	"	"
50	4	58	375	110	456	10300	50	74	29½	61	24	16
	"	"	"	220	224	"	"	"	"	"	"	"
	"	"	425	500	98	"	"	"	"	"	"	"
60	6	70	400	110	525	8700	76	68⅝	31¾	60¼	32	16
	"	"	"	220	263	"	"	"	"	"	"	"
	4	"	550	220	263	7500	50	73¾	27¾	55¾	20	18¼
	"	"	600	500	115	"	"	"	"	"	"	"
75	6	85	500	110	630	7800	76	71	31¾	60¼	32	16
	"	"	"	220	315	"	"	"	"	"	"	"
	4	"	325	220	315	13900	60⅝	87⅝	34½	69⅝	30	19
	"	"	"	500	137	"	"	"	"	"	"	"
100	6	115	400	110	850	13200	87	83½	33$\frac{13}{16}$	63$\frac{11}{16}$	38	20
	"	"	"	220	427	"	"	"	"	"	"	"
	4	"	550	220	427	13900	60⅝	87⅝	34½	69⅝	25	19
	"	"	"	500	186	"	"	"	"	"	"	"
250	8	290	350	220	1100	29000	104	126	43½	83½	46	32
	"	"	375	500	485	"	"	"	"	"	"	"

"C. & C." ELECTRIC MOTOR COMPANY. STANDARD MOTORS.

Type, No.	H. P.	Pulley.		Speed.	Floor Space.	Height.
		Diam.	Face.			
1	⅛	1½"	Grooved	2200	9 x 6	9
2	¼	3 "	2	2100	9 x 13	12
3	½	3 "	2	2000	10 x 14	13½
5	1	4 "	2½	1900	10 x 14	15
7	2	5 "	3	1775	11 x 23	16
8	3	6 "	4	1650	11 x 25	16
10	4	6 "	4	1550	12 x 27	16
12	5	7 "	4	1475	14½ x 28¾	18
16	7	8 "	5	1400	14½ x 29½	18
18	8	8 "	5	1300	14½ x 30	18
20	10	9 "	6	1200	16 x 33	21
30	15	10 "	7	1050	16 x 37	21
40	20	11 "	8	950	18 x 41½	24
50	25	12 "	9	800	18 x 45	24

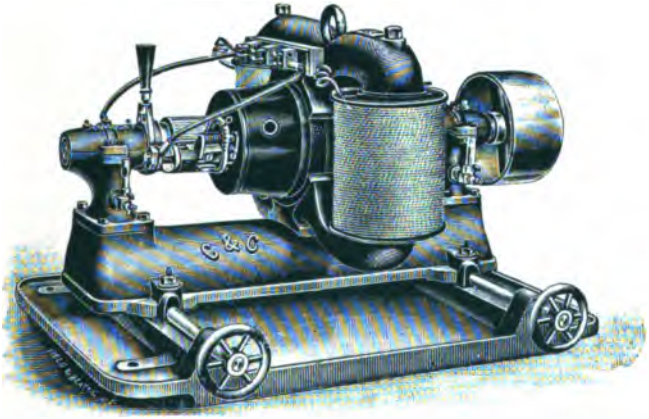
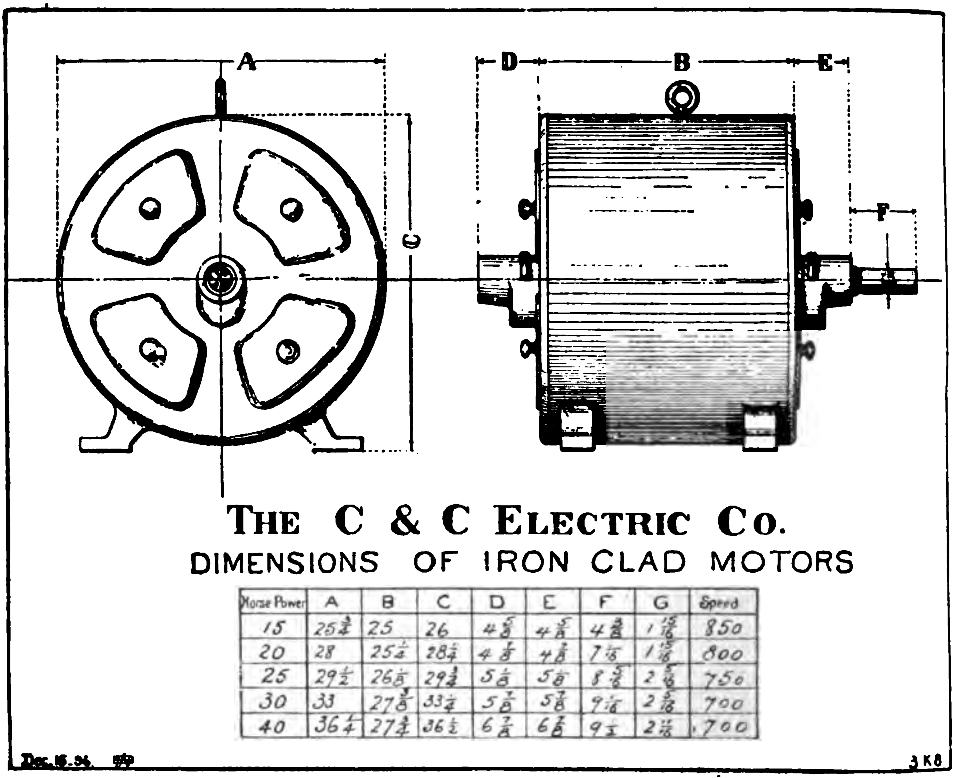


Fig. 268—"C. & C." Electric Motor.

A "C and C" motor, connected to a hoist, is shown in Fig. 272. The armature shaft is connected with the hoist shaft by intermediate gearing. The sizes and weights of these are shown in the accompanying table.



THE C & C ELECTRIC CO.

DIMENSIONS OF IRON CLAD MOTORS

Horse Power	A	B	C	D	E	F	G	Speed
15	$25\frac{3}{4}$	25	26	$4\frac{5}{8}$	$4\frac{5}{8}$	$4\frac{3}{8}$	$1\frac{15}{16}$	850
20	28	$25\frac{1}{4}$	$28\frac{1}{4}$	$4\frac{7}{8}$	$4\frac{7}{8}$	$7\frac{1}{16}$	$1\frac{15}{16}$	800
25	$29\frac{1}{2}$	$26\frac{1}{8}$	$29\frac{3}{4}$	$5\frac{1}{8}$	$5\frac{1}{8}$	$8\frac{5}{8}$	$2\frac{5}{16}$	750
30	33	$27\frac{3}{8}$	$33\frac{1}{4}$	$5\frac{7}{8}$	$5\frac{7}{8}$	$9\frac{1}{16}$	$2\frac{5}{16}$	700
40	$36\frac{1}{4}$	$27\frac{3}{4}$	$36\frac{1}{2}$	$6\frac{7}{8}$	$6\frac{7}{8}$	$9\frac{1}{2}$	$2\frac{11}{16}$	700

Fig. 271—Dimensions of "C. & C." Iron-Clad Motors.

DATA OF ELECTRIC HOISTS DRIVEN BY "C. & C." MOTORS.

H. P. Motors.	Velocity in Feet per Minute.					
	50	100	150	200	250	300
	Weight, Pounds.					
5	1386					
7½	3464	1732	1155			
10	4620	2310	1540	1155		
15		3465	2310	1732	1386	1155
20		4620	3080	2310	1840	1540
25			3850	2877	2310	1925
30				3465	2790	2295
40					3700	3077
50						3850

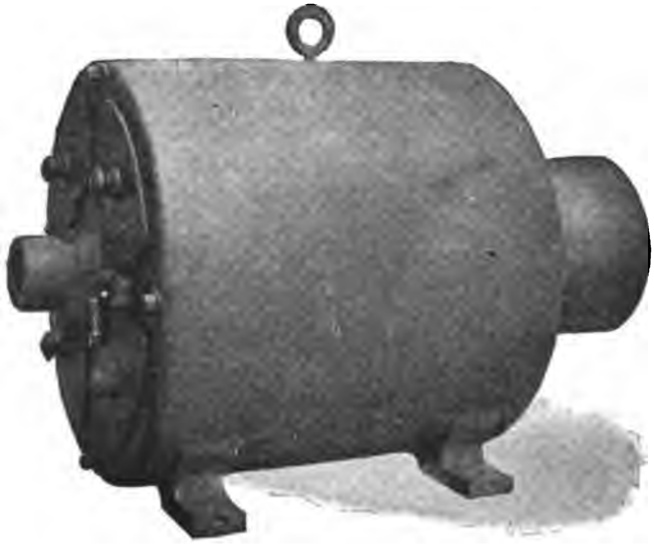


Fig. 269—"C. & C." Quadripolar Iron-Clad Motor.—Closed.

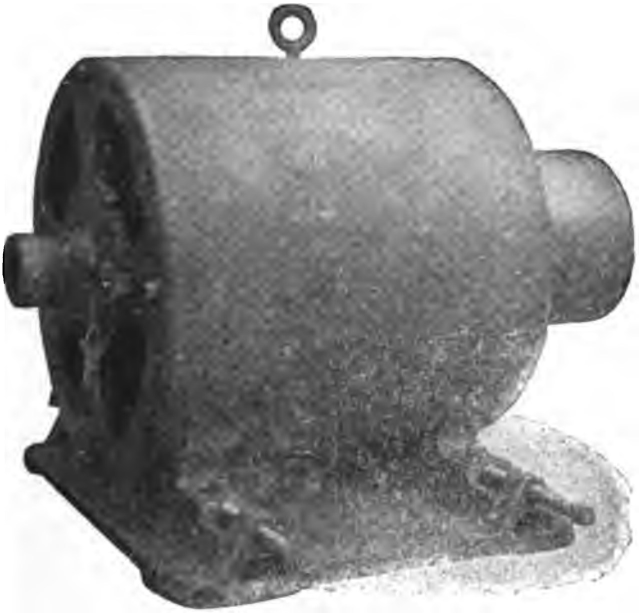


Fig. 270—"C. & C." Quadripolar Iron-Clad Motor.—Open.

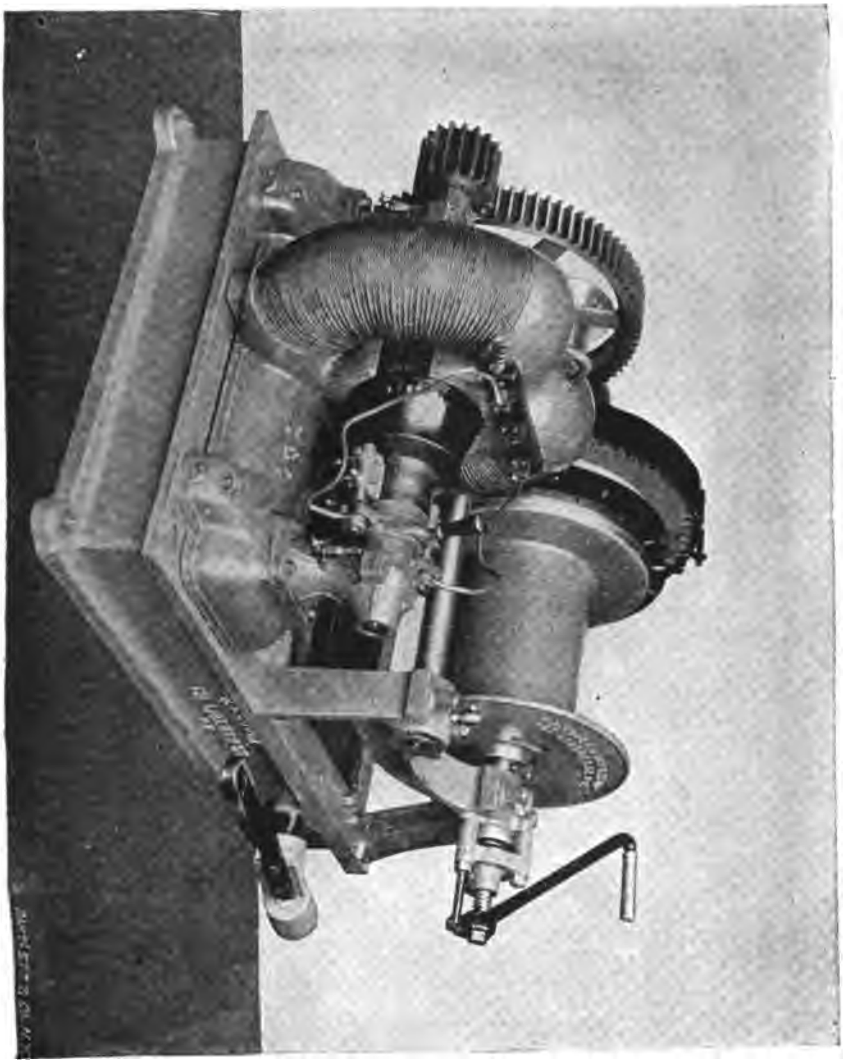


Fig. 272—"C. & C. Motor Connected to Electric Hoist,

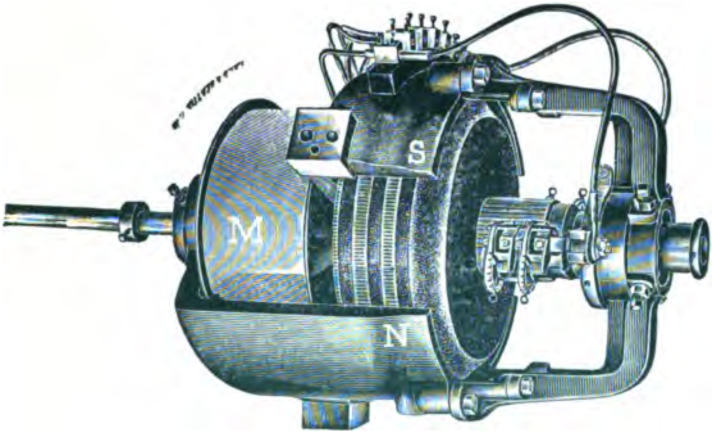


Fig. 273—"C. & C." Boat Motor.

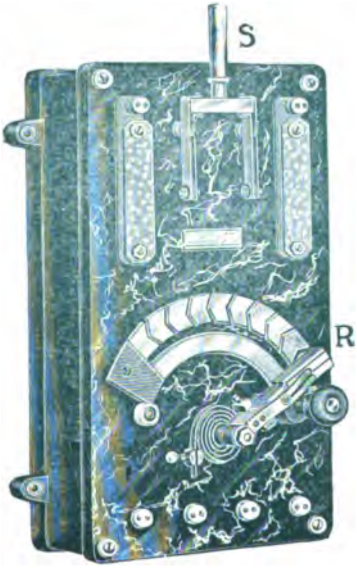


Fig. 274—"C. & C." Motor Starting-Box.

Fig. 273, shows a form of "C and C" motor, suitable for driving small boats in conjunction with a storage battery. Here, a field magnet coil M, produces a bipolar field N, S, in which the armature is placed.

The "C and C" motor starting-box, is shown in Fig. 274.

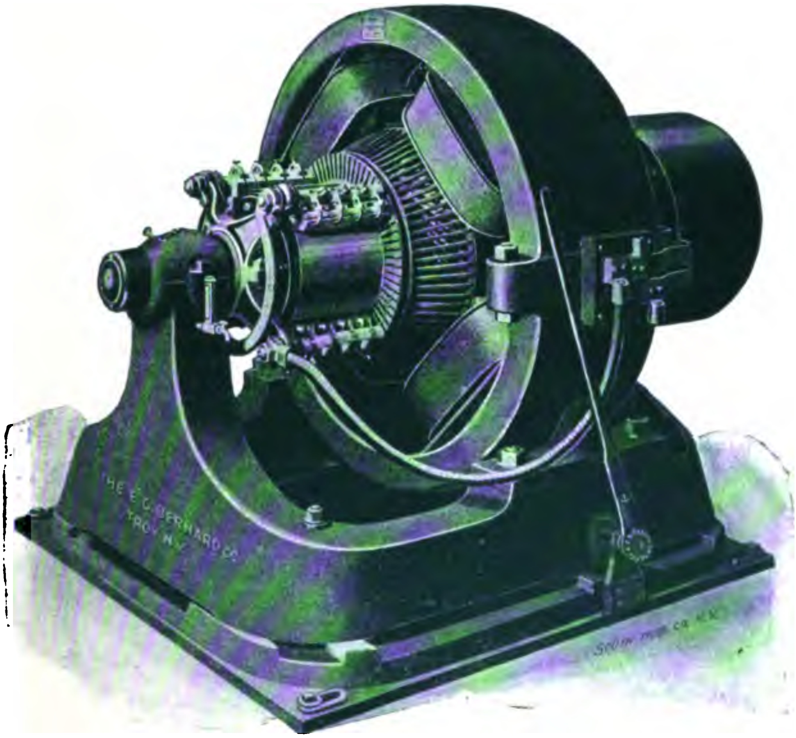


Fig. 274 A—E. G. Bernard Company's Motor.

The diagram of its connection has already been shown in Fig. 264.

It contains a double-pole switch S, and a starting rheostat R. The contact lever of this rheostat is pressed back towards the off-contact position, by the spiral spring shown. When the motor is started, the switch S, is first closed, thereby magnetizing the field, and the contact lever R, is moved slowly to the left, against the tension of a spiral spring. This allows the current to flow in the proper strength through the armature, and start the same. When the motor has reached full speed, the contact lever R, is pushed as far to the right as it can be moved. It then becomes locked in position by a magnetically controlled detent. Should the current through the motor become excessive; i. e., should the motor be in danger of overheating by excessive current, the magnetic device releases the contact lever and allows it to return to its off-contact position, under the influence of the spiral spring. The same result will occur should the current through the motor cease altogether, as would follow an interruption of the electric supply. In either event, therefore, the armature of the motor is automatically cut out of circuit.

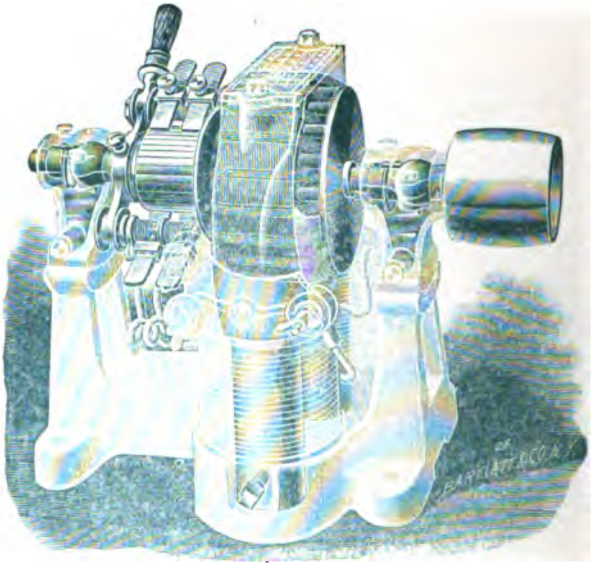

BARTLETT & CO. N.Y.

Fig. 275.—Crocker-Wheeler Motor.

Fig. 274 A, shows a compound-wound multipolar motor of the E. G. Bernard Company.

The Crocker-Wheeler Electric Company's motor, as constructed in sizes from $\frac{1}{6}$th to 2 H. P. inclusive, is shown in Fig. 275. This is a bipolar motor of the upright type. The frame or base is of cast iron, and soft iron or cast steel cores are let into the receptacles in the base and clamped firmly in position by screw clamps. The poles and the magnet cores are made in one piece. In sizes from 3 to 10 H. P. inclusive, the field-magnets are single horse-shoe castings of soft cast-steel, let into the cast-iron base. The parts of this motor, disassembled, are shown in Fig. 276. The armatures are iron clad, and their method of winding is shown in Fig. 277. The core plates are ring-shaped iron discs, the armature winding being what is called a Gramme-ring winding, with the coils placed in grooves as shown.

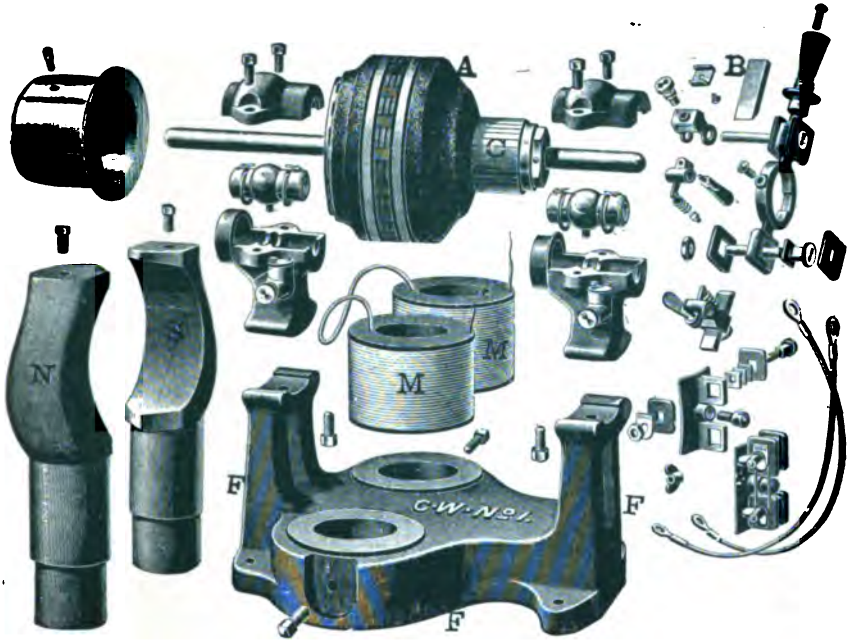


Fig. 276—Parts of Crocker-Wheeler Standard Motors.

The dimensions of the Crocker-Wheeler motors are given in Fig. 278, in connection with the accompanying table.

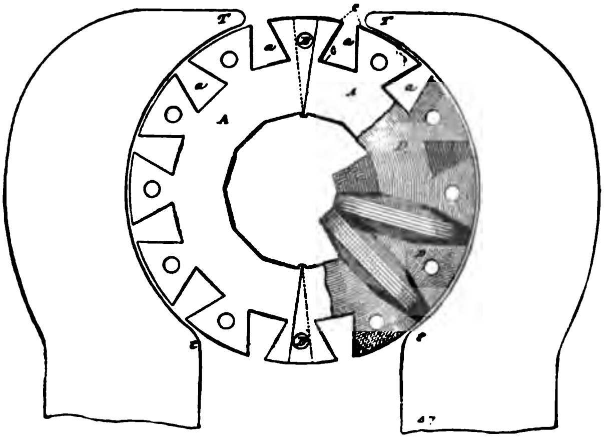


Fig. 277—Crocker-Wheeler Armature.

GENERAL DIMENSIONS OF STANDARD CROCKER-WHEELER MOTORS.

H. P.	Speed.	Pulley.		Dimensions over all.			F	G	H	I	J
		A. Diameter.	B. Face.	C. Length.	D. Breadth.	E. Height.	Length Between Bolt Holes.	Breadth Between Bolt Holes.	Height of Shaft Centre from Base of Motor.	Diameter Armature.	Diameter Shaft.
$\frac{1}{12}$	1900	$1\frac{1}{2}$	$\frac{5}{8}$	$7\frac{11}{16}$	$5\frac{1}{4}$	$7\frac{7}{8}$	$4\frac{3}{4}$	$2\frac{3}{4}$	$5\frac{11}{16}$	$3\frac{3}{8}$	$\frac{3}{8}$
$\frac{1}{6}$	1800	$2\frac{1}{2}$	$1\frac{1}{4}$	$9\frac{1}{2}$	$6\frac{1}{2}$	$8\frac{1}{2}$	$6\frac{5}{8}$	$3\frac{5}{8}$	$6\frac{1}{8}$	$3\frac{5}{8}$	$\frac{1}{2}$
$\frac{1}{4}$	1400	3	$2\frac{1}{4}$	$14\frac{13}{16}$	$8\frac{5}{8}$	$10\frac{11}{16}$	$9\frac{25}{32}$	$4\frac{5}{16}$	$7\frac{3}{4}$	$4\frac{15}{16}$	$\frac{9}{16}$
$\frac{1}{2}$	1250	$3\frac{1}{2}$	3	$17\frac{3}{4}$	10	$12\frac{9}{16}$	$11\frac{7}{16}$	$5\frac{1}{4}$	9	$5\frac{5}{8}$	$\frac{11}{16}$
1	1000	4	$3\frac{1}{2}$	$19\frac{1}{4}$	$13\frac{1}{4}$	15	$12\frac{7}{16}$	7	$10\frac{3}{8}$	7	$\frac{7}{8}$
2	1000	5	4	$22\frac{1}{2}$	$14\frac{1}{4}$	$17\frac{3}{8}$	$14\frac{7}{8}$	7	$11\frac{1}{16}$	$7\frac{3}{4}$	1
3	950	6	4	$26\frac{5}{8}$	$16\frac{3}{16}$	$18\frac{5}{8}$	$18\frac{1}{16}$	$9\frac{3}{16}$	$11\frac{13}{16}$	$8\frac{1}{4}$	1
5	950	$7\frac{1}{2}$	$4\frac{1}{2}$	$28\frac{1}{16}$	$19\frac{1}{4}$	$21\frac{3}{8}$	19	$9\frac{3}{4}$	$13\frac{5}{8}$	$9\frac{3}{16}$	$1\frac{1}{4}$
$7\frac{1}{2}$	900	9	6	$28\frac{1}{16}$	$19\frac{1}{4}$	$21\frac{7}{8}$	19	$9\frac{3}{4}$	$13\frac{5}{8}$	$9\frac{3}{16}$	$1\frac{1}{4}$
10	850	9	7	$36\frac{1}{4}$	24	$26\frac{3}{4}$	$24\frac{1}{2}$	13	$17\frac{1}{4}$	11	$1\frac{1}{2}$
15	800	11	8	40	$30\frac{5}{8}$	$30\frac{7}{8}$	$25\frac{5}{16}$	14	$15\frac{7}{16}$	11	$1\frac{3}{4}$
40	700	15	11	$54\frac{1}{2}$	36	$41\frac{1}{2}$	$34\frac{1}{8}$	$22\frac{1}{4}$	$19\frac{1}{4}$	15	$2\frac{3}{8}$

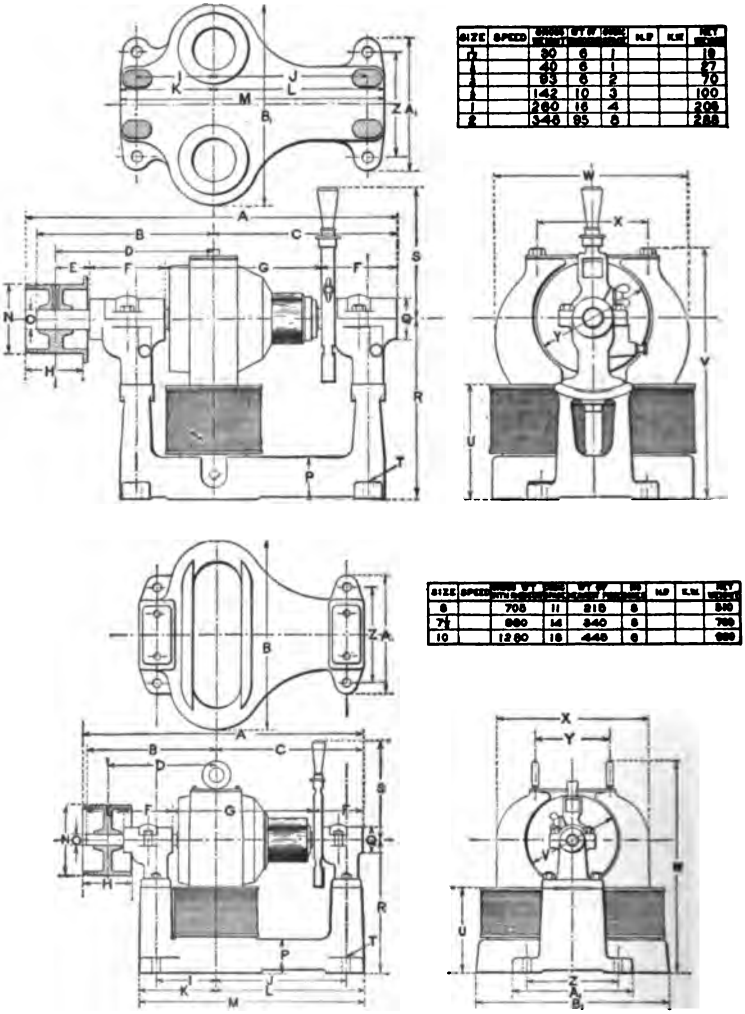
SHIPPING WEIGHTS AND DIMENSIONS OF STANDARD MOTORS.

H. P.	Net Weight.		Shipping Weight.		Shipping Dimensions.	
	Motor.	Regulator.	Motor.	Regulator.	Motor.	Regulator.
1/12	17		28		8½ x 9 x 19⅛	
⅙	26		34		10⅞ x 9 x 9½	
¼	70	5	95	14	19 x 11½ x 13¾	8½ x 9 x 10⅛
½	106	15	141	25	22 x 13½ x 15½	11 x 11 x 18
1	201	27½	245	45¼	22¾ x 15¾ x 17⅝	13 x 13 x 14
2	281	27½	342	45¼	30¾ x 20½ x 22	13 x 13 x 14
3	364	71	435	115	34 x 21½ x 23	19¾ x 14¾ x 15⅝
5	590	71	678	115	37 x 24½ x 27¼	19¾ x 14¾ x 15⅝
7½	590	72	678	116	37 x 24½ x 27¼	19¾ x 14¾ x 15⅝
10	1065	74	1400	118	46¼ x 31 x 36¾	19¾ x 14¾ x 15⅝
15	1450	78	2000	122	52 x 39⅝ x 42⅝	19¾ x 14¾ x 15⅝

The Crocker-Wheeler standard motors are multipolar in sizes above 10 H. P.

Fig. 279, shows a Crocker-Wheeler Electric Company's 2-100 octopolar motor, suitable for direct connection to machinery. It is called a 2-100 motor because it yields 2 H. P., when running at 100 revolutions per minute. With the same torque, therefore, it supplies 3 H. P. at 150 revolutions per minute, or 4 H. P. at 200 revolutions per minute. It is designed to permit of wide variations of speed-control by the usual methods of regulation. There are 8 sets of brushes, mounted so as to avoid the use of cross-connecting cables. The field frame is of cast-iron with steel poles cast into the frame. The pole faces are split clamp collars which are rigidly attached to the cores by tightening screws, and which hold the coils in place. The field frame somewhat overhangs the machine, not only protecting the field coils, but also affording a convenient bolting surface for the various attachments. The supporting lugs L, are cast in various shapes to conform to the machines to be driven. T, T, are the armature terminals, t, t, the field terminals.

A Crocker-Wheeler Electric Company's size 22 mill motor, is seen in Fig. 280. This motor is not intended for railway work, although it is constructed on similar lines. It is



SIZE	SPEED	[illegible]	[illegible]	[illegible]	H.P	K.W	[illegible]
[illegible]		30	6	1			19
[illegible]		40	6	1			27
[illegible]		93	6	2			70
[illegible]		142	10	3			100
1		260	16	4			206
2		348	85	6			288

SIZE	SPEED	[illegible]	[illegible]	[illegible]	[illegible]	H.P	K.W	[illegible]
6		705	11	210	6			510
7½		960	14	340	6			[illegible]
10		1280	18	445	6			[illegible]

Fig. 278—Dimensions of Crocker-Wheeler Motors.

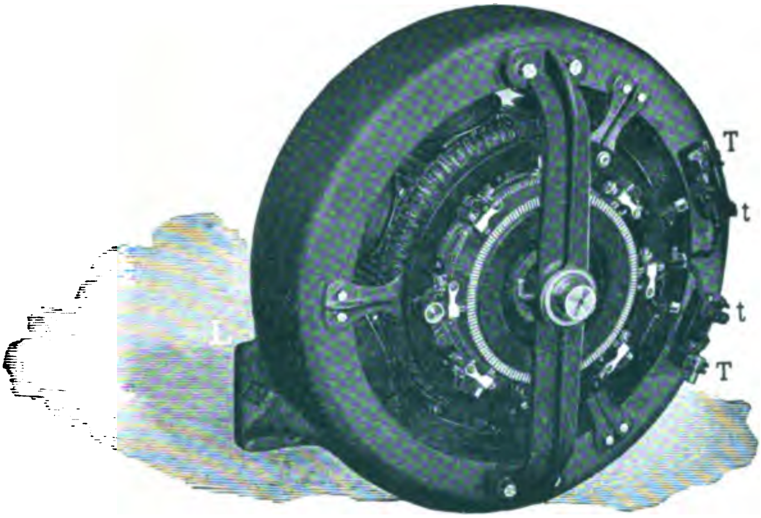


Fig. 279.—Crocker-Wheeler Size 2-100 Motor. For Direct Connection.

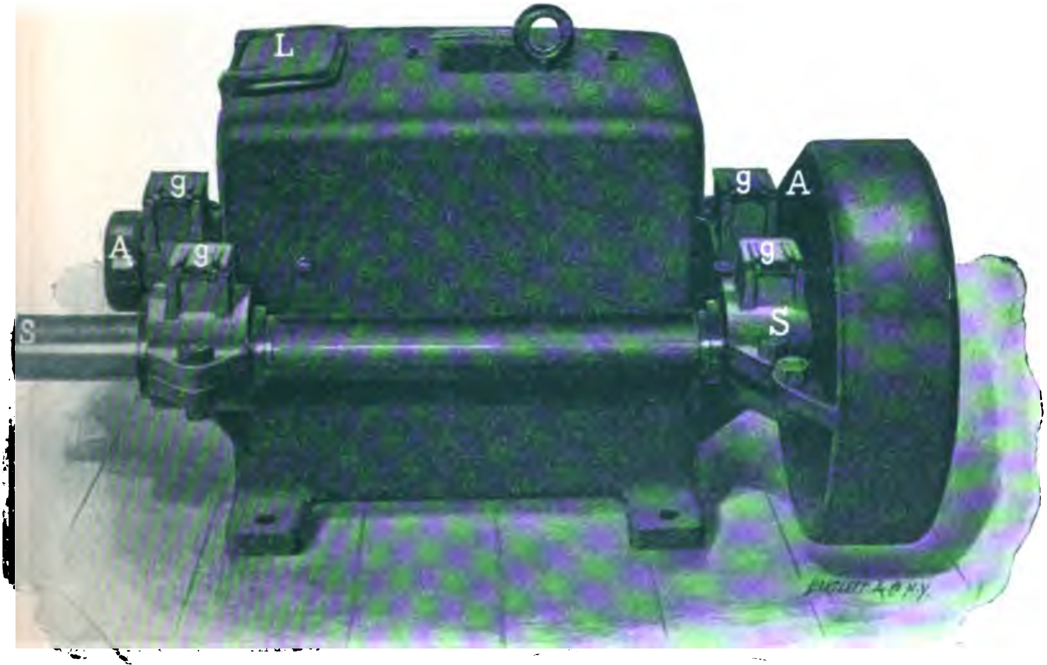


Fig. 280—Crocker-Wheeler Size 22 Mill Motor.

designed for driving machinery in mills where the dust is destructive to motors of the ordinary open type. Lubrication is effected through the closed grease cups, g, g, g, g. A, A, is the motor axle geared, in the ratio 1:3.94, with the shaft S S. The weight of the machine is 1,675 pounds, and its output is 22 H. P. on intermittent work. The lid L, gives access to the brushes.

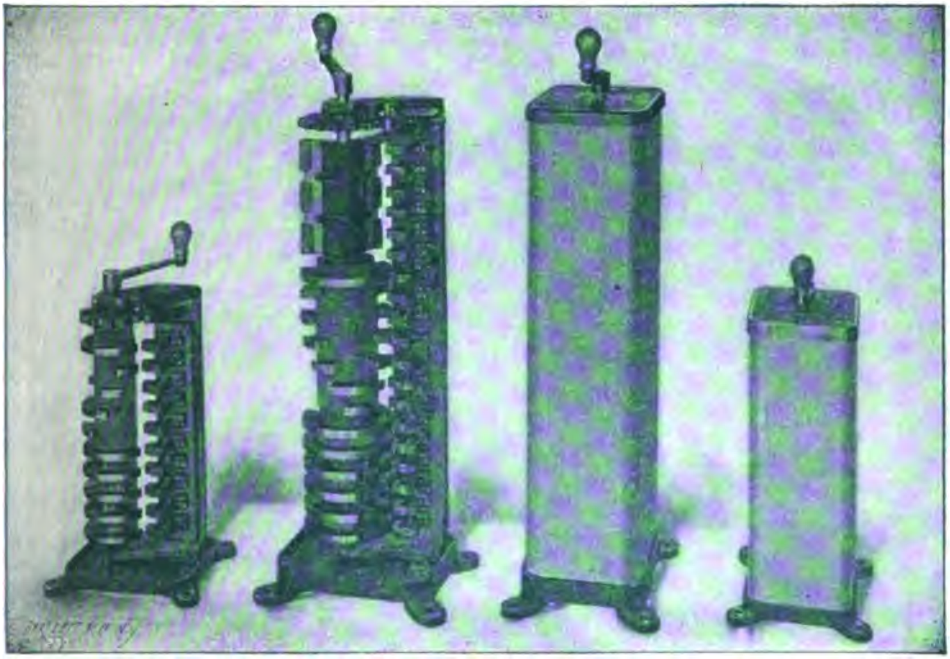


Fig. 281—Crocker-Wheeler Controllers.

Two sizes of Crocker-Wheeler Electric Company's Controller for stopping, starting, reversing and controlling the speed of stationary series-wound motors are shown in Fig. 281. They are shown both with their covers in place and removed, These controllers are provided with a number of segmental contact rings for establishing the necessary armature and field contacts in the proper order.

Fig. 282, shows a Crocker-Wheeler 1 H. P. motor connected to a Worthington "house-service" pump, by a belt. The large outboard idler pulley I, presses upon the belt and keeps it in contact with more than half the periphery of the small motor pulley. By this means a very considerable speed reduction is effected between the motor pulley and the pump pulley P, which drives the plunger p. i, is the pump-intake, and o, the outlet.

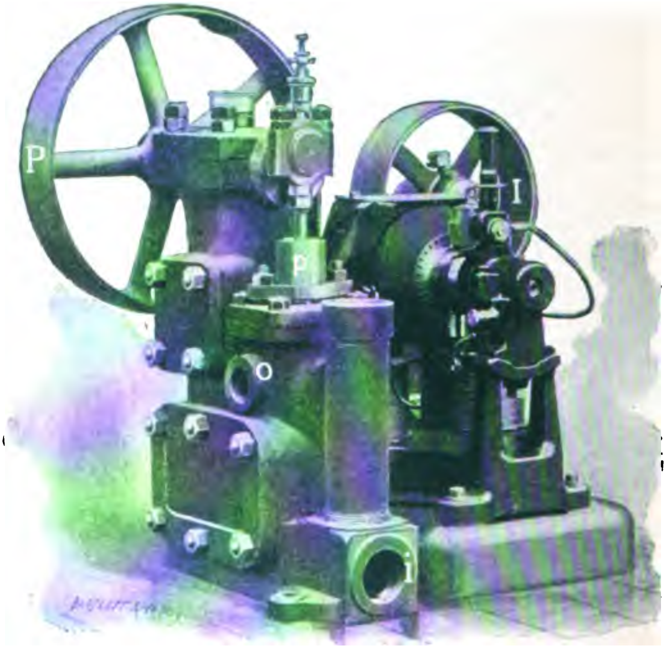


Fig. 282—Crocker-Wheeler Size 1 Motor, Belted to Worthington "House-Service" Pump.

A $\frac{1}{6}$th H. P. Crocker-Wheeler motor is shown in Fig. 283. This motor has no separate starting box, but is operated by a switch S, supported on one of the pole pieces. T, T, are the main terminals. The connections of the switch are shown in Fig. 284. Here, the armature A, is connected between terminal T, and spring 1. A starting resistance s, which is wound on the field coils, is placed between spring 1 and spring 2. The field coils are connected between T, and spring 3, while spring 4, is connected to terminal T'. A semicircular metallic plate, attached to the handle of the switch S, makes contact with these springs in succession. On closing the switch, it first closes the field circuit through 3 and 4, then closes the armature circuit through the resistance s, and, finally, closes the armature circuit through 4 and 1, short-circuiting the starting resistance s.

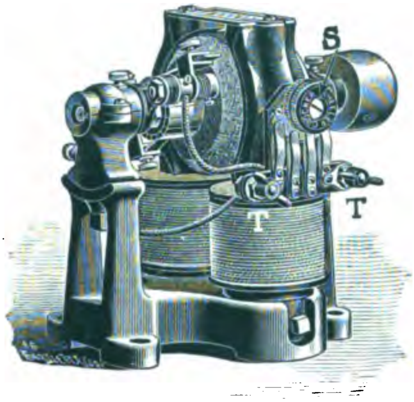


Fig. 283—16 H. P. Crocker-Wheeler Motor.

A similar switch is placed on type "T," of the Crocker-Wheeler fan motors, which are intended to operate at either of two speeds; namely, half speed and full speed. The connections of this switch are shown in Fig. 285. The armature a, is connected between spring 1, and the terminal T. One field coil b, is connected between springs 1 and 3, while the other field coil c, is connected between springs 2 and 4. When the motor is run at half speed, these field coils are in series, and oppose a greater resistance to the current. When running at full speed, the field coils are in parallel and offer a reduced resistance. A and B, are two metal plates, which are insulated from each other, and serve to make the necessary connections. It will be observed that the motor illustrated in Fig. 284 is a shunt motor, that is to say, the armature is in shunt, or in parallel, with the field-magnets; while the motor illustrated in Fig. 285, is a series motor, that is to

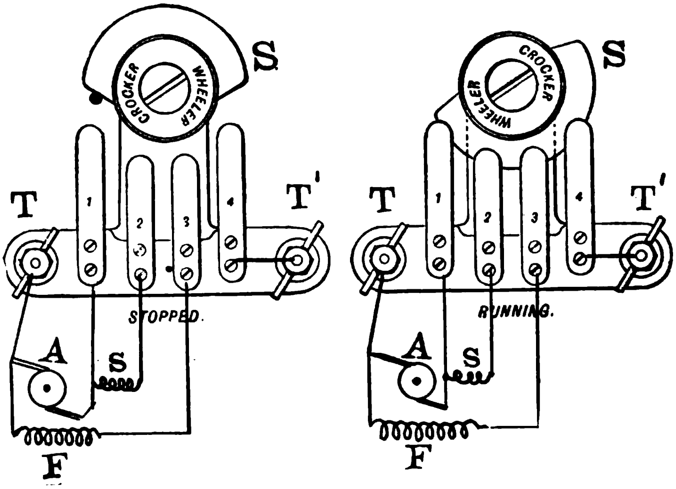


Fig. 284—Connections of Switch on 1-6 H. P. Crocker-Wheeler Motor.

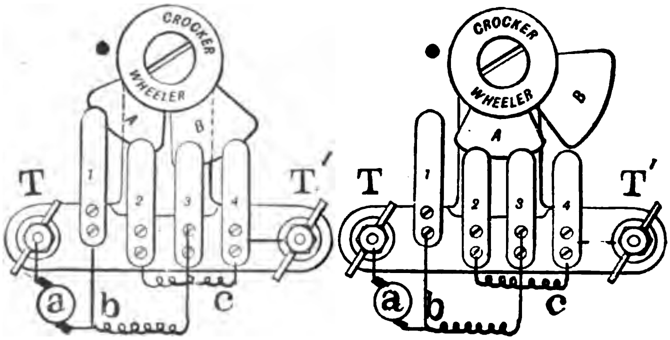


Fig. 285—Connections of Double-Speed Crocker-Wheeler Switch.

say, the armature is in series with the field-magnets. The latter plan greatly reduces the cost of construction of very small motors, since it enables comparatively coarse wire to

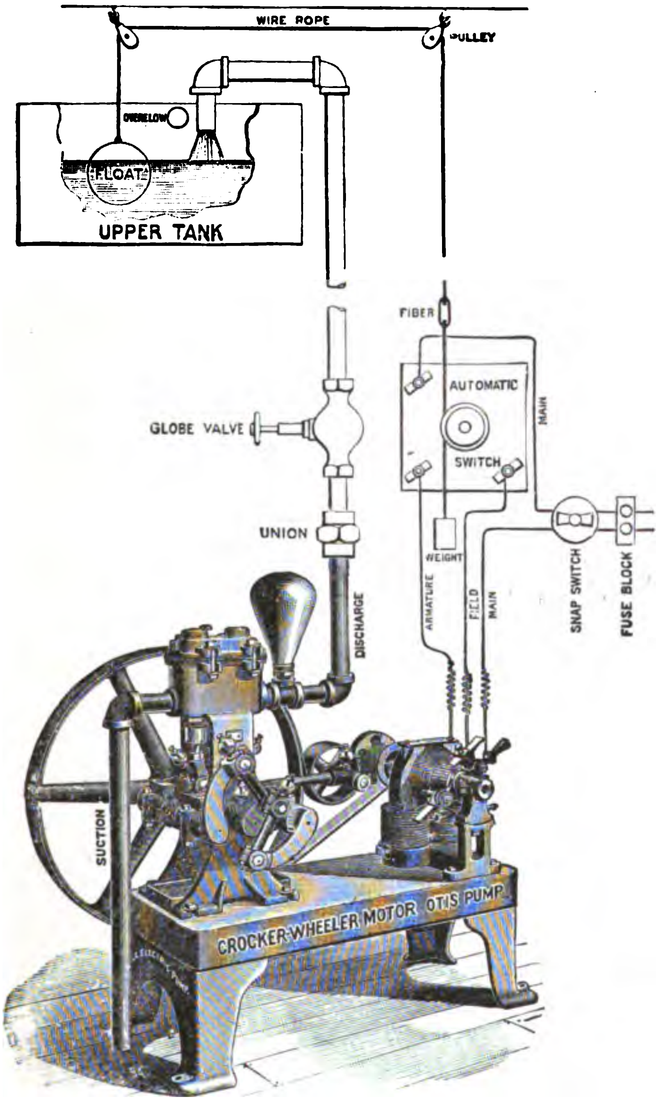


Fig. 286—Crocker-Wheeler Motor and Otis Pump.

be wound on the field coils, and a shunt winding would require to be made of very fine, and, therefore, comparatively expensive wire. This is particularly the case with 500-volt motors; in fact it is almost impossible, in practice, to make a 500 volt ⅙ H. P. motor with a shunt winding.

Fig. 286, shows a Crocker-Wheeler motor attached by a belt to an Otis house pump, and arranged for filling a tank at the top of the house. Here, the water level in the tank controls the automatic switch by the float shown. The switch first closes the shunt-field circuit and then the armature circuit. The sizes and capacities of these plants are indicated in the accompanying table.

CROCKER-WHEELER PUMPING OUTFITS. OTIS ELECTRIC PUMP.

Number of Pump.	1	2	3	4	5	6	7	8
Revolutions per Minute....	125	125	100	100	100	100	100	100
Displacement per Revolution......	.04	.053	.083	.166	.332	.50	.664	.883
Gallons per Minute.	5	6.66	8.33	16.66	33.32	50.00	66.64	83.30
Capacity per Hour.	300	400	650	1,000	2,000	3,000	4,000	5,000
Quantity, 24 Hours	7,200	9,600	15,600	24,000	48,000	71,000	96,000	120,000
Height in Feet....	60	80	100	125	150	150	200	200
Size of Discharge..	½	¾	1	1¼	1½	2	3	3½
Size of Suction....	¾	1	1¼	1½	2	2½	3½	4
H. P. of Motor....	⅙	¼	½	1	2	3	4	5

Fig. 287, shows the connections for standard Crocker-Wheeler shunt motors, with starting boxes. The switch lever of the starting box is in permanent connection with the terminal marked MAIN. At the position of the switch indicated in the figure, the motor is disconnected at both field and armature. On turning the switch, the field circuit is first closed, and then the armature circuit, through a resistance which is gradually cut out, until the main terminal is connected directly through the switch lever to the armature as well as to the field.

The Lundell standard motor is shown in Fig. 289. It is

a four-pole machine with one pair of brushes. The dimensions of these motors is given on page .

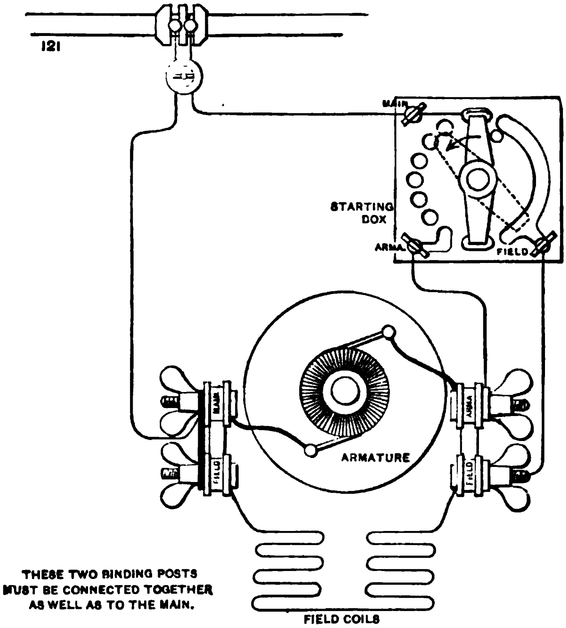

121
MAIN
STARTING BOX
ARM.
FIELD
MAIN
ARMA
FIELD
FIELD
ARMATURE
THESE TWO BINDING POSTS MUST BE CONNECTED TOGETHER AS WELL AS TO THE MAIN.
FIELD COILS

Fig. 287—Connections for Standard Crocker-Wheeler Shunt Motors.

A Lundell bipolar fan motor directly connected to an exhaust fan is shown in Fig. 290. The sizes and speeds of these motors are given in the accompanying table.

COMBINED EXHAUST FANS AND LUNDELL DIRECT-CONNECTED MOTORS.

Size of Fan, Inches.	Speed. Revs. per min.	Motor. Horse-power.	Amperes at 115 Volts.
18	1000	¼	1.5
24	775	½	3.
30	650	1	5.
36	600	2	10.
42	550	4	20.
48	500	5	25.
60	400	10	30.
72	350	15	50.

A cross-section of the $\frac{1}{12}$ and $\frac{1}{6}$ H. P. Lundell motors is shown in Fig. 291. M M, is a single series field-coil which produces a north pole at N, and a south pole beneath the armature at S. The armature is a small iron-clad drum with its commutator at C. The carbon brushes in this case are small rods, which are pressed endwise against the commutator by spiral springs represented in Fig. 292.

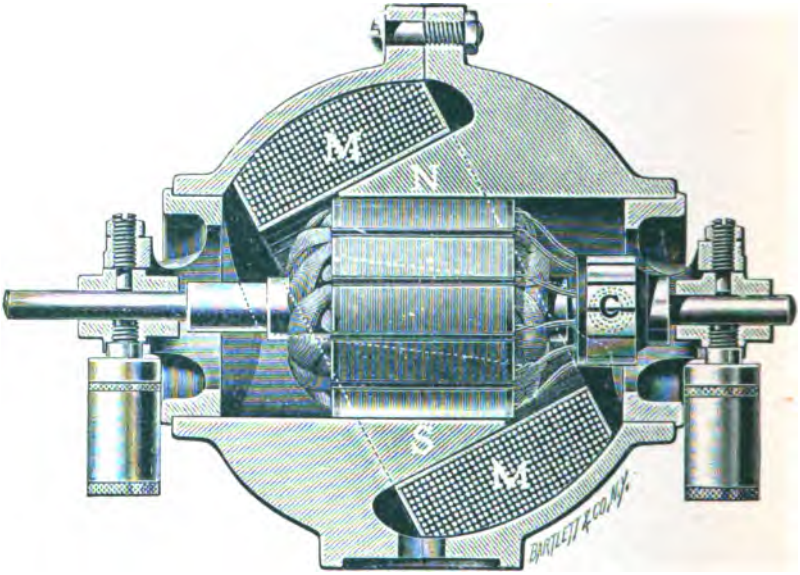


Fig. 291—Parts 1-12 and 1-6 H. P. Lundell Motors.

A Storey Motor and Tool Company's motor is shown in Fig. 293. The horizontal and vertical longitudinal section of this motor appear in Fig. 294. m, m, are two cylindrical magnetizing coils which produce north poles n, n, at the sides of the armature a, and south poles s, s, above and below it. On the left hand side is the commutator with its brushes. Fig. 295, shows a Storey motor used as a buffer. The dimensions of these motors are given in the accompanying table in connection with Fig. 296. These machines are also employed as generators, both belt-driven and direct-connected.

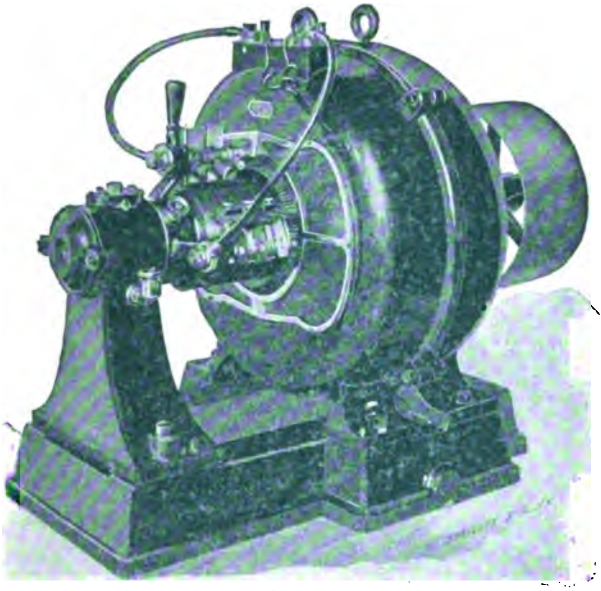


Fig. 289—Lundell Standard Motor.

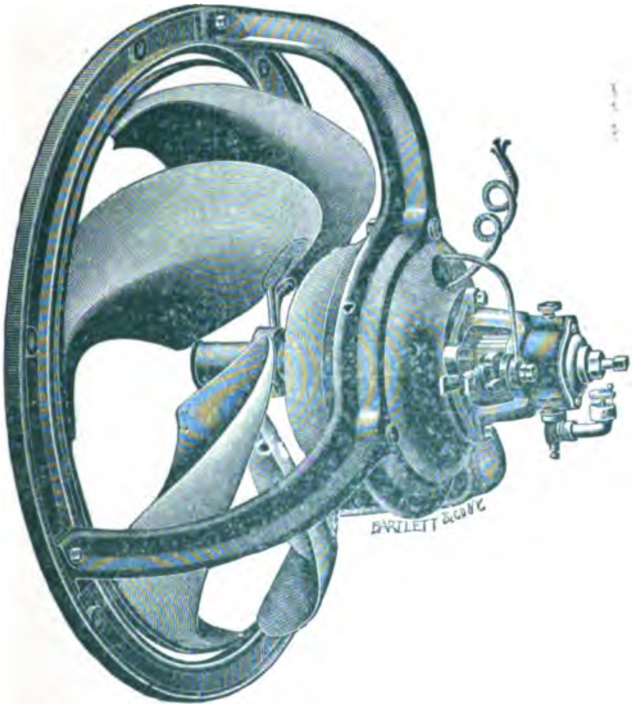


Fig. 290—Lundell Exhaust Fan and Motor.

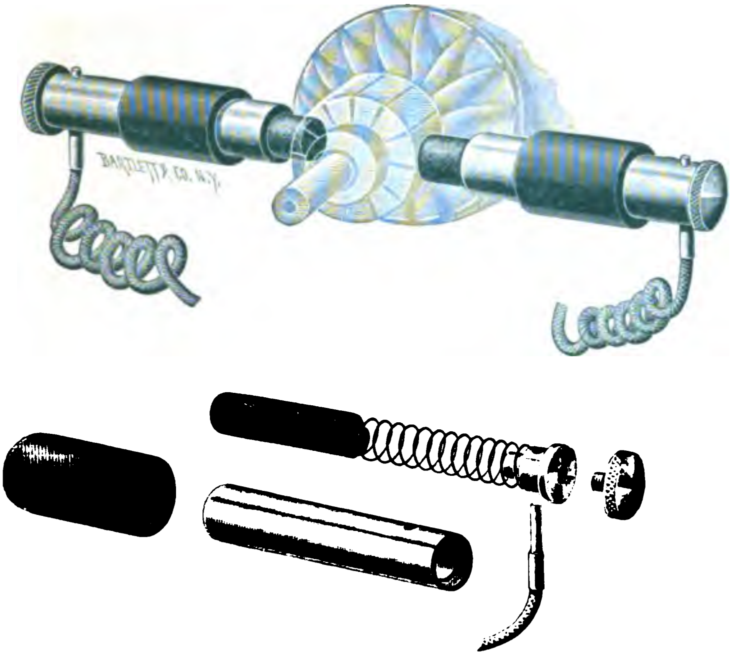


Fig. 292—Brushes of Lundell Fan Motor.

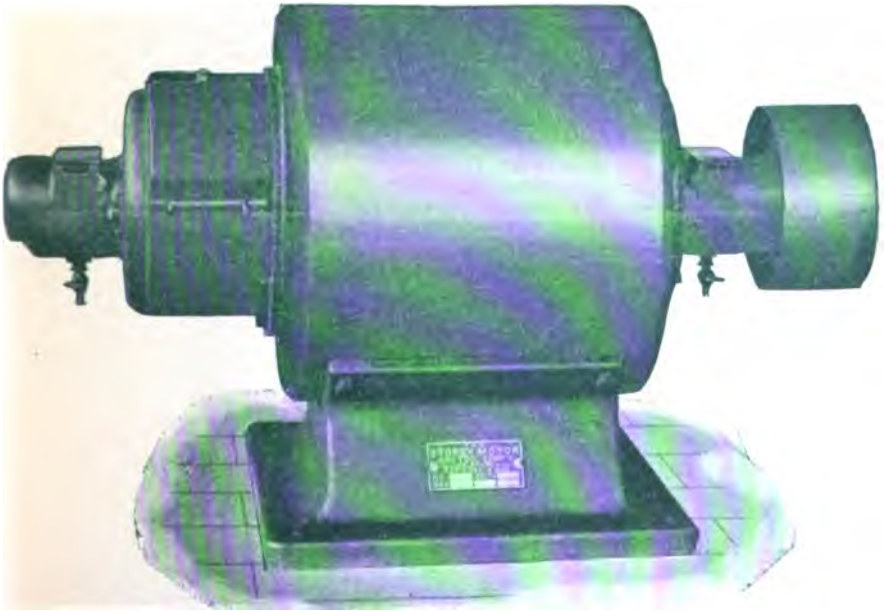


Fig. 293—Type of Storey Standard Power Motor and Dynamo.

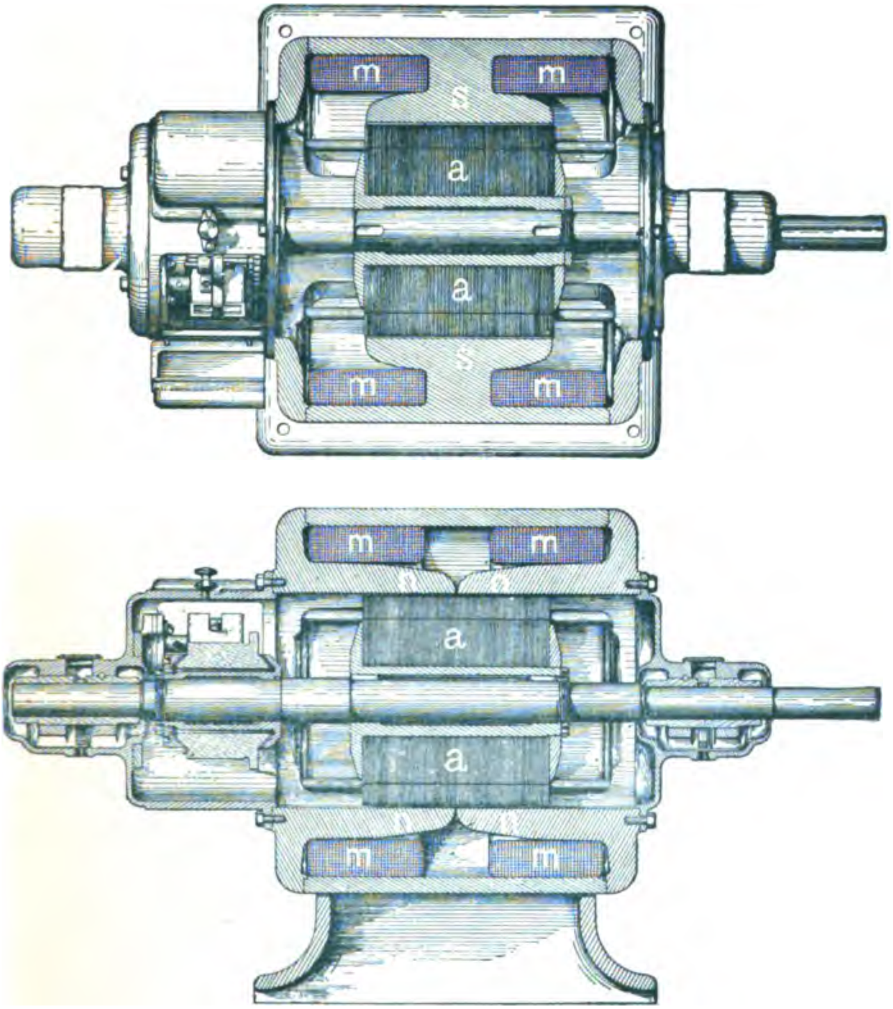


Fig. 294—Horizontal and Vertical Sectional Views of Storey Motors.

TABLE OF THE STOREY MOTOR AND TOOL COMPANY'S MOTORS.

Size of Motor.	Gross Weight.	DIMENSIONS.												
		A	B	C	D	E	F	G	H	I	J	K	L	M
No. 2	88 lbs.	$19\frac{7}{16}$"	$7\frac{1}{2}$"	8 "	8 "	$6\frac{3}{4}$ "	$\frac{5}{16}$"	$2\frac{1}{4}$ "	$3\frac{3}{4}$ "	$8\frac{1}{2}$"	$2\frac{3}{4}$ "	$1\frac{15}{16}$"	$4\frac{1}{2}$"	$\frac{9}{16}$"
" 3	120 "	$22\frac{15}{16}$"	$9\frac{1}{2}$"	10 "	10 "	$7\frac{3}{4}$ "	$\frac{3}{8}$"	$2\frac{7}{8}$ "	$4\frac{5}{8}$ "	$9\frac{1}{2}$"	$3\frac{1}{2}$ "	$2\frac{7}{16}$"	$4\frac{7}{8}$"	$\frac{11}{16}$"
" 4	220 "	$25\frac{1}{8}$ "	$11\frac{1}{2}$"	$11\frac{1}{4}$"	$11\frac{1}{4}$"	$8\frac{3}{4}$ "	$\frac{3}{8}$"	$3\frac{1}{4}$ "	$4\frac{3}{4}$ "	$10\frac{1}{2}$"	4 "	$2\frac{5}{8}$ "	$6\frac{1}{8}$"	$\frac{15}{16}$"
" 5	330 "	$29\frac{15}{16}$"	14 "	14 "	$14\frac{1}{2}$"	$11\frac{1}{16}$"	$\frac{1}{2}$"	4 "	$4\frac{13}{16}$"	13 "	$4\frac{13}{16}$"	$3\frac{5}{16}$"	$7\frac{1}{4}$"	$1\frac{1}{16}$"
" 6	425 "	$30\frac{1}{2}$ "	$15\frac{1}{8}$"	12 "	$14\frac{1}{2}$"	$11\frac{13}{16}$"	$\frac{1}{2}$"	$4\frac{3}{16}$"	$5\frac{5}{16}$"	$12\frac{1}{4}$"	$5\frac{1}{8}$ "	$3\frac{1}{2}$ "	$8\frac{1}{8}$"	$1\frac{5}{16}$"
" 7	630 "	$33\frac{3}{4}$ "	$15\frac{1}{8}$"	15 "	17 "	$12\frac{1}{4}$ "	$\frac{1}{2}$"	$4\frac{3}{16}$"	$5\frac{5}{16}$"	$15\frac{1}{2}$"	$5\frac{1}{8}$ "	$3\frac{5}{8}$ "	$8\frac{1}{8}$"	$1\frac{5}{16}$"
" 8	850 "	$37\frac{1}{8}$ "	18 "	16 "	19 "	14 "	$\frac{5}{8}$"	$5\frac{1}{8}$ "	$6\frac{7}{16}$"	15 "	$5\frac{9}{16}$"	5 "	$10\frac{3}{8}$"	$1\frac{7}{16}$"
" 9	1050 "	$45\frac{1}{8}$ "	19 "	17 "	20 "	$14\frac{1}{2}$ "	$\frac{5}{8}$"	$6\frac{3}{16}$"	$7\frac{15}{16}$"	18 "	$6\frac{3}{4}$ "	$6\frac{1}{4}$ "	$10\frac{3}{8}$"	$1\frac{11}{16}$"
" 10	1450 "	$52\frac{1}{8}$ "	$22\frac{1}{2}$"	21 "	$23\frac{1}{2}$"	$16\frac{1}{4}$ "	$\frac{3}{4}$"	7 "	10 "	20 "	8 "	$7\frac{1}{8}$ "	$12\frac{3}{8}$"	$1\frac{15}{16}$"

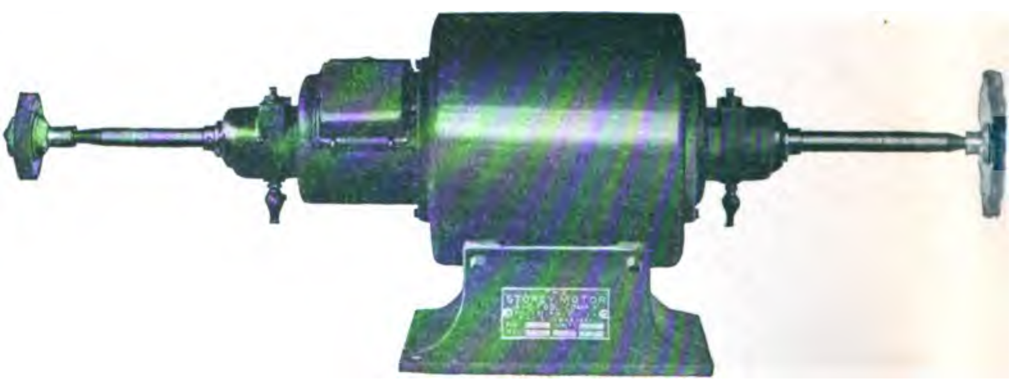


Fig. 295—Storey Standard Buffer.

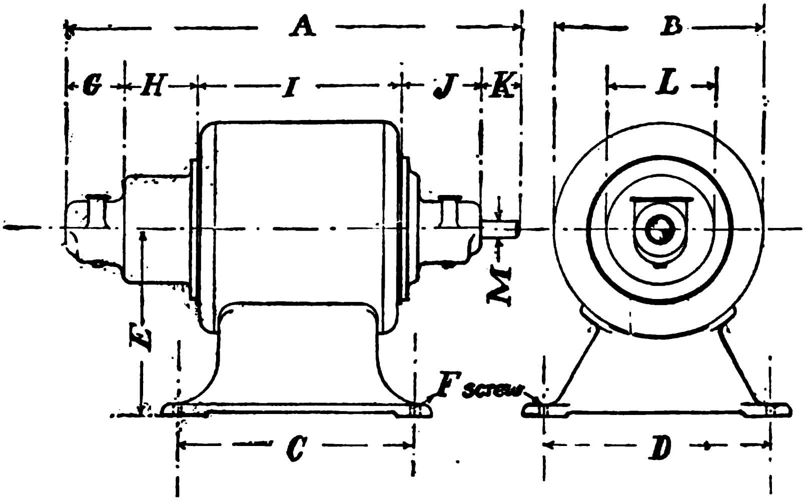


Fig. 296—Dimensions of the Storey Motor.

Figs. 297 and 298 show other types of Storey Motor and Tool Company's Motor. The dimensions of these motors are given in the accompanying tables.

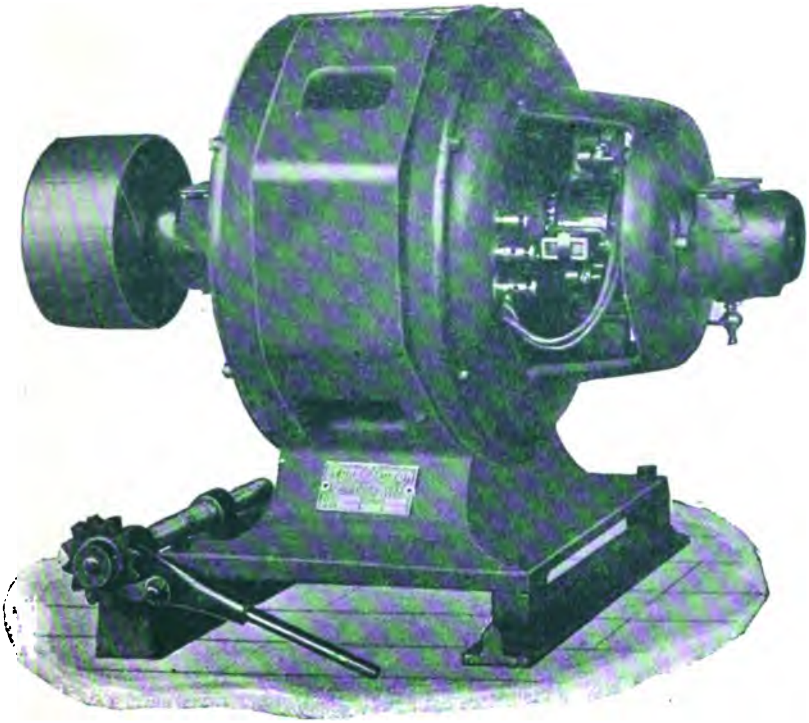


Fig. 297—Storey Motor Enclosed Type.

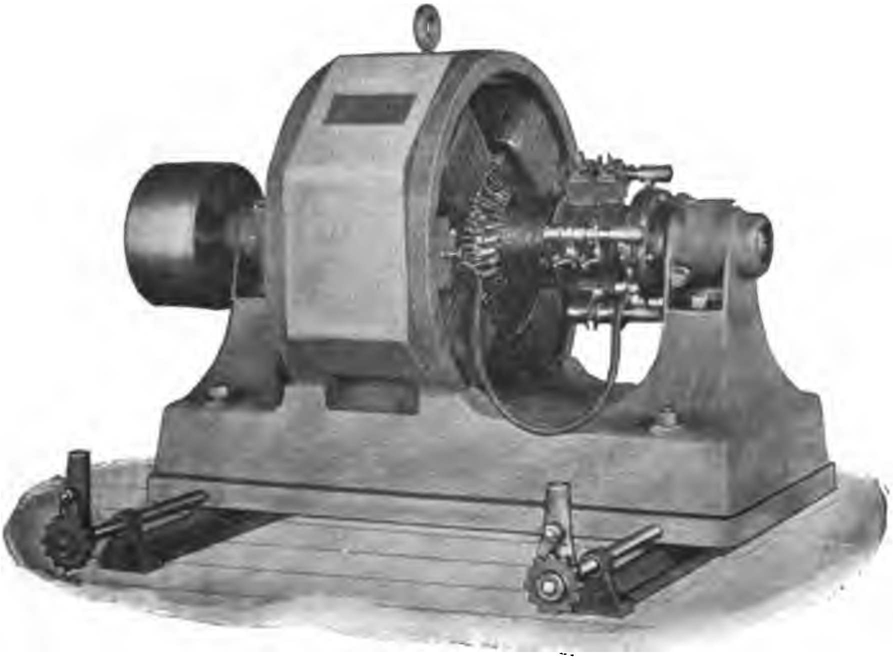


Fig. 298—Storey Quadripolar Motor.

STOREY MULTIPOLAR MOTORS. SHUNT WOUND.

Size.	H. P.	Medium Speed.	H. P.	Slow Speed.	Diameter Pulley.	Width Belt.
2	¾	2200	½	1100	3	1½
3	1¼	2000	¾	1000	4	2
4	2	1800	1	900	5	2½
5	3	1600	2	900	6	3
6	5	1400	3	800	7	3½
7	7½	1200	5	800	7	4
8	10	1000	7½	700	8	4½
9	15	1000	10	700	9	6
10	20	900	15	600	10	7½
11	25	800	20	600	12	8
12	35	800	25	500	13	10
13	50	750	35	500	14	12

SERIES WOUND.

Size.	H. P.	Medium Speed.	H. P.	Slow Speed.	Diameter Pulley.	Width Belt.
2	¾	2000	½	1000	3	1½
3	1¼	1800	¾	900	4	2
4	2	1700	1	850	5	2½
5	3	1500	2	900	6	3
6	5	1300	3	700	7	3½
7	7½	1050	5	650	7	4
8	10	900	7½	600	8	4½
9	15	800	10	550	9	6
10	20	700	15	500	10	7½
11	25	650	20	500	12	8
12	35	600	25	450	13	10
13	50	550	35	450	14	12

An Ahlm-Edwards Electric Company's 3 H. P. quadripolar motor, fastened to a wall or post, is illustrated in Fig. 299. The armature winding of this motor is represented in Fig. 300, and the principal dimensions are shown in the accompanying table.

Fig. 301, shows a Royal Electric Company's belt-driving bipolar motor. These machines are also employed as generators. Their data are given in the accompanying table.

The motors are wound for 110, 220, and 500 volts. This is the usual practice in winding motors, since 110 volts is the ordinary two-wire incandescent lighting pressure; 220 volts, is the three-wire incandescent lighting pressure between outside mains, and it is preferable to operate motors from the outside mains of such system, since thereby the motor load cannot unbalance the system. 500-volt windings are suitable

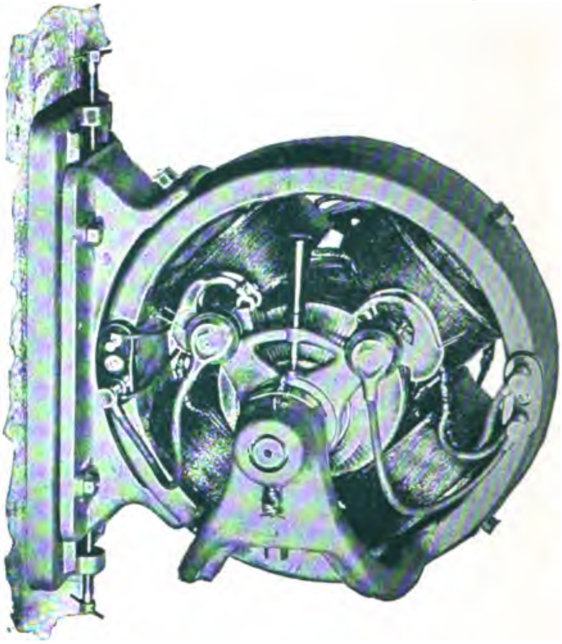
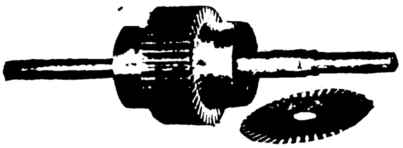


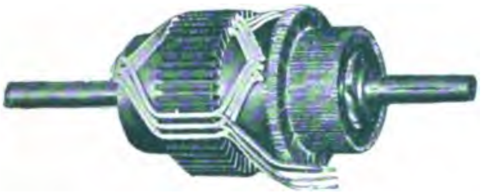
Fig. 299—2 H. P. Ahlm-Edwards Motor 1100 R.R.M. Fastened to Wall or Post.

THE AHLM-EDWARDS ELECTRIC COMPANY.

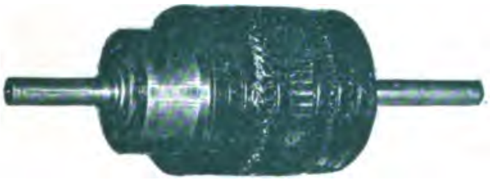
SLOW-SPEED MOTORS. 110-220-500 VOLTS.					MODERATE-SPEED MOTORS. 110-220-500 Volts.			
Class.	4½-15.	6-13	7-12	8-11	Class.	6-13	7-12	8-11
H. P........	½	1	2	3	H. P........	2	3	5
R. P. M.....	1500	1300	1200	1100	R. P. M.....	2000	1900	1800
Weight	80	170	325	445	Weight	170	325	445
Pulley. Diam...	4	4½	5	6	Pulley. Diam...	3½	4	5
Pulley. Face....	2	3	3	3½	Pulley. Face....	3	3	3½
Pulley. Bore....	⅞	1	1⅛	1¼	Pulley. Bore....	1	1⅛	1¼



Armature Core and Disk.



Armature Core with Commutator Showing Method of Winding.



Complete Armature.

Fig. 300—Armature Winding of Ahlm-Edwards Motor.

DATA OF ROYAL ELECTRIC COMPANY'S DIRECT-CURRENT MOTORS.

Capacity in Horse Power.	Speed R. P. M.	Diameter of Pulley.	Width of Belt.	Floor Space in Inches.	Approximate Weight in Pounds.
3	1500	7	2	28 x 28	650
5	1400	8	3	35 x 30	1000
10	1300	10	4	45 x 35	2000
15	1200	10	5	48 x 38	3000
20	1200	11	7	50 x 42	3250
25	1200	12	7	55 x 42	3600
30	1150	13	10	64 x 48	5000
40	1000	14	11	66 x 50	6800
50	900	16	13	72 x 56	7500
70	800	18	14	78 x 60	8500

for railway and power circuits. Where a small machine may have any one of these three windings, it has usually the greatest margin of power above its rated capacity, in the 110-volt winding, for the reason that while, theoretically, 220-volt, or 500-volt windings should afford just as much carrying capacity at a given load, as a 110-volt winding, yet, in practice,

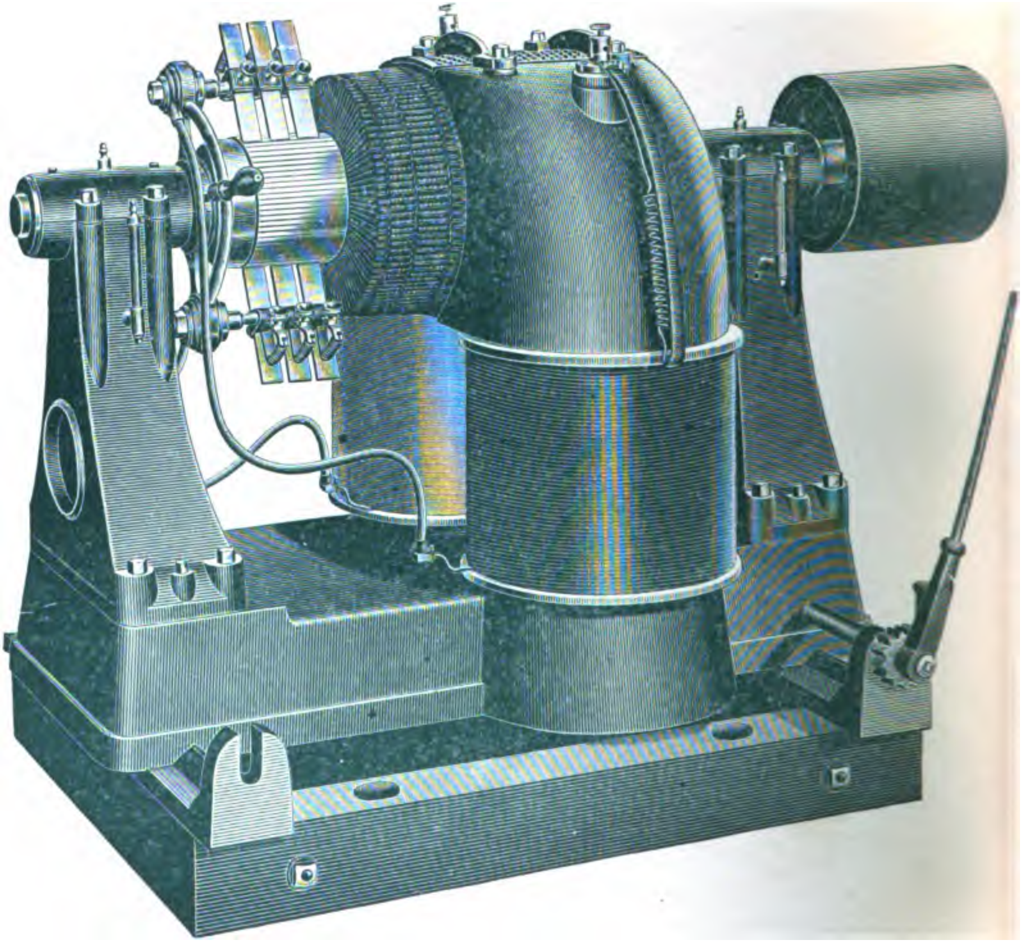


Fig. 301—Royal Electric Belt-Driven Bipolar Motor.

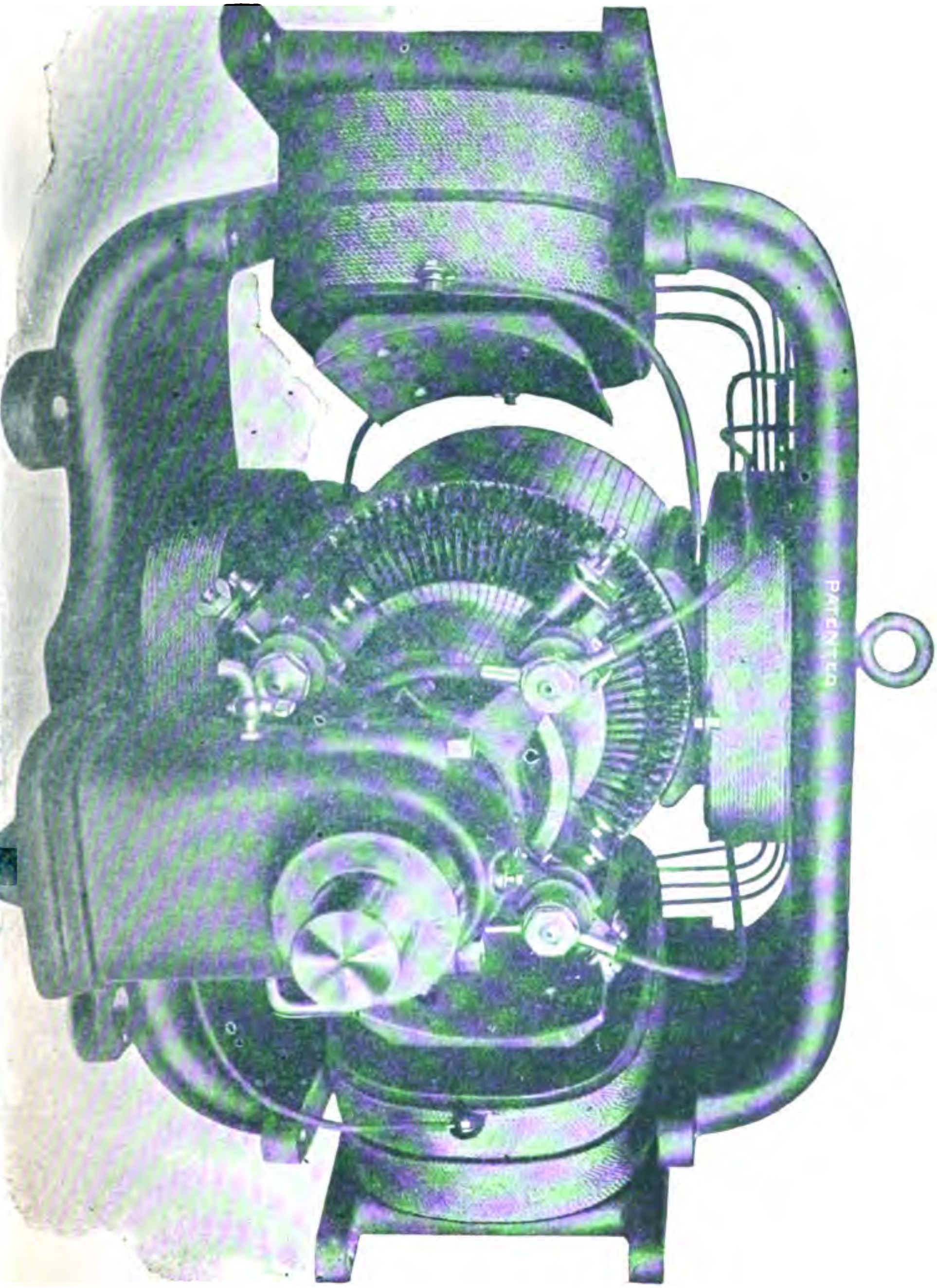


Fig. 302—Keystone Electric Elevator Motor.

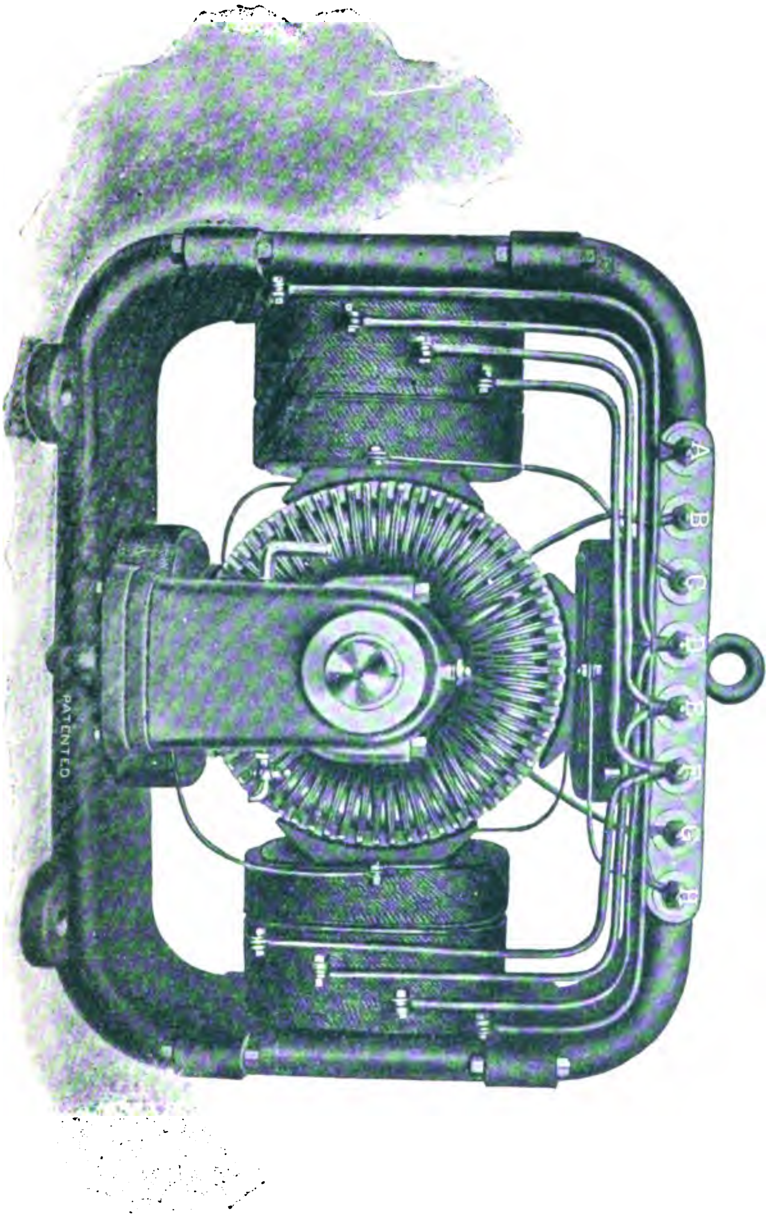


Fig. 803—Rear View of "Keystone" Electric Elevator Motor.

the insulation of the wire in a 500-volt winding occupies a relatively greater amount of the winding space, and, consequently, the higher voltage winding has to sacrifice some copper, and, therefore, some carrying capacity. This difference, however, practically disappears in larger machines.

Fig. 302, represents a Keystone Electric Company's elevator motor. This is a quadripolar, compound-wound machine. The two magnets on the sides are capable of being released and swung around as shown, in order to give free access to the armature for inspection or removal.

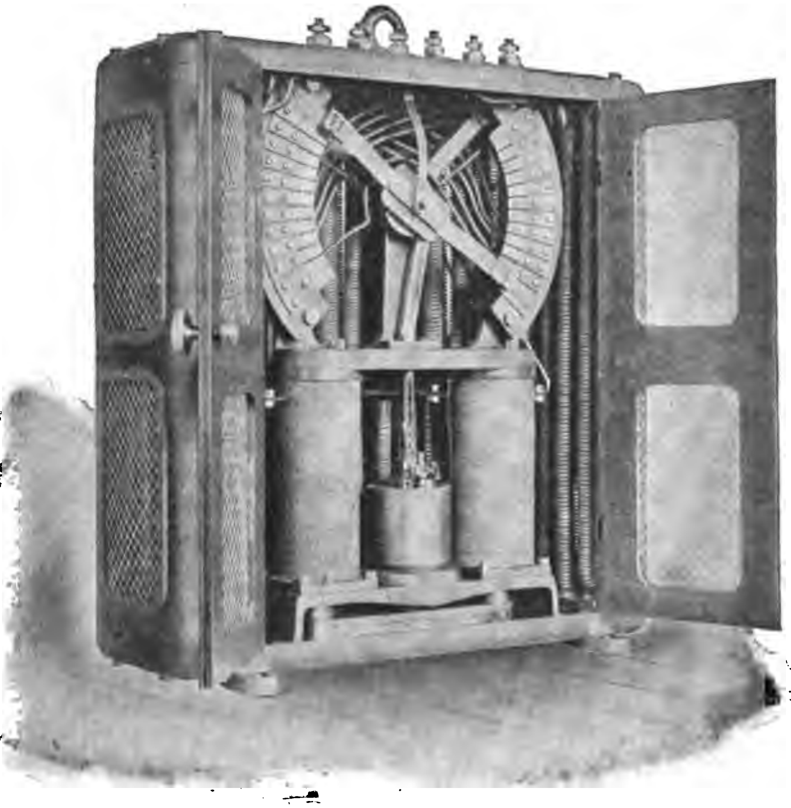


Fig. 304—"Keystone" Automatic Rheostat.

Fig. 303, shows the rear view of this motor. Terminals

A, D, E and F, lead to the sections of the series field-windings. Terminals C and H, lead to the shunt field-windings, while terminals B and G, lead to the brushes and armature. An automatic rheostat shown in Fig. 304, is employed with

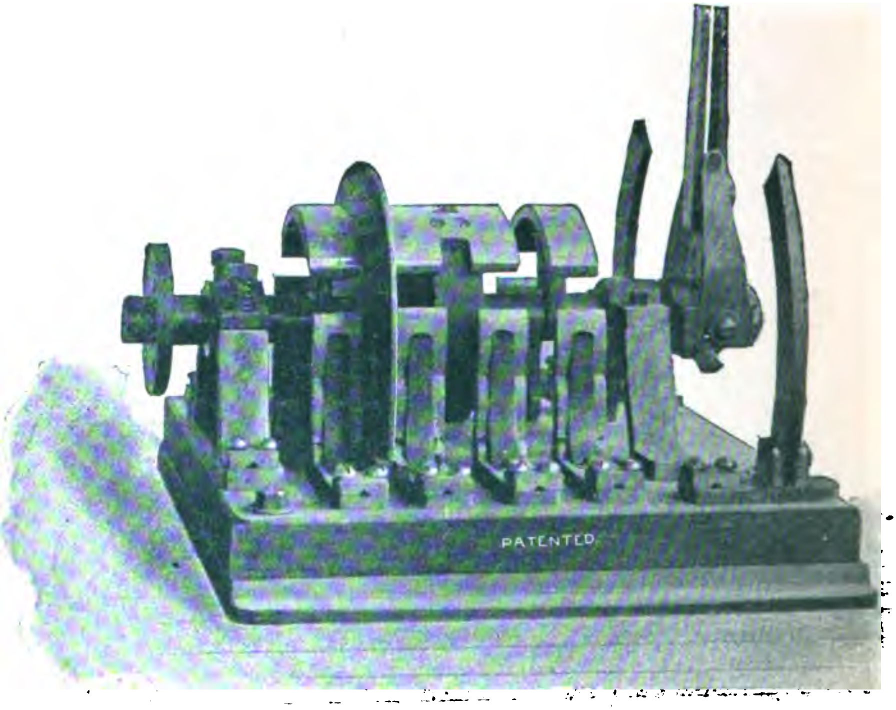


Fig. 305—Reversing Switch of "Keystone" Electric Elevator Motor.

this elevator motor. This automatic rheostat has the resistance coil shown, placed normally in the circuit of the armature. Two solenoids, placed in a shunt circuit, act upon two cores connected by a yoke, carrying a plunger, and operating in a dash-pot. The plunger is also connected at its upper end to a steel strip, coiled around a wheel or pulley connected with a pair of arms. When the solenoids are unexcited the tension on the strip brings the arms, to the position shown, in which their extremities, armed with carbon brushes, rest on the terminal segment plates. When the solenoids are energized, they attract their armatures and release the tension on the strip, whereby a cóil spring, not shown in the figure, causes the arms to rotate in a counter-clockwise direction, or towards the final contact plates. When the motor is started, the current in its armature circuit enters the rheostat, passes through the strip, to the arms, and there dividing, enters the resistance coils, the terminal segment plates, finally leaving the rheostat by a terminal, connected with the final contact plates. When the solenoids, are energized, the strip is released, and the arm commences to descend, sudden movements being resisted by the dash-pot. As the arms move over the contact plates, the resistance in the armature circuit is reduced.

Fig. 305, shows a form of reversing switch of the Keystone Electric Company's elevator motor.

The Card Electric Company's 5-H. P. multipolar motor is shown in Fig. 306. This motor is entirely encased with the exception of the commutator brushes, which are left free for inspection. The apparatus frequently employed to control this motor is represented in Fig. 307. On the left-hand side the apparatus is at the "off position," while on the right-hand side the apparatus is represented at the "on" or "working position." S, is a double-pole switch, which is thrown up, or closed by hand, and kept in position by detent under the control of the electromagnet M. The rheostat r, is placed in the armature circuit, and its coils are placed in the ventilated box R. On turning the switch clockwise, the motor is brought to full speed, when the lever is caught by a magnetic detent m. Should the motor become overloaded, the magnet M, will attract its armature, and drop its detent when the current through the motor is 25% in excess of the full-load value. This will release the main switch S, which will fly open under the action of a suitable spring. The magnet m, will also release and allow the rheostat lever to return to its "off position." Again, if the current should be accidentally turned off the mains, so that the motor has to stop, the magnet M, will drop its lower armature, thereby releasing the switch S, and the magnet m, will also release the switch handle. Consequently, the motor will be thrown out of circuit, and the resistance R, will be restored to its armature circuit, if the current be excessive or if it should fail.

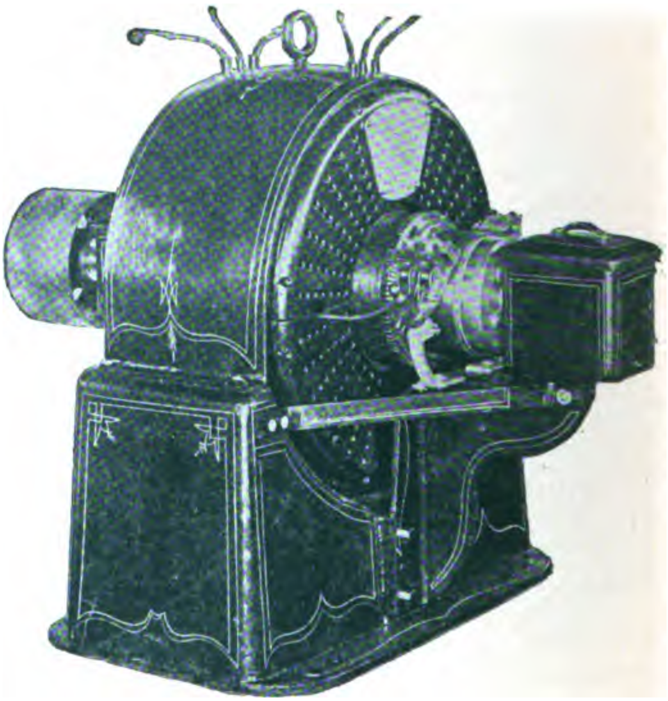
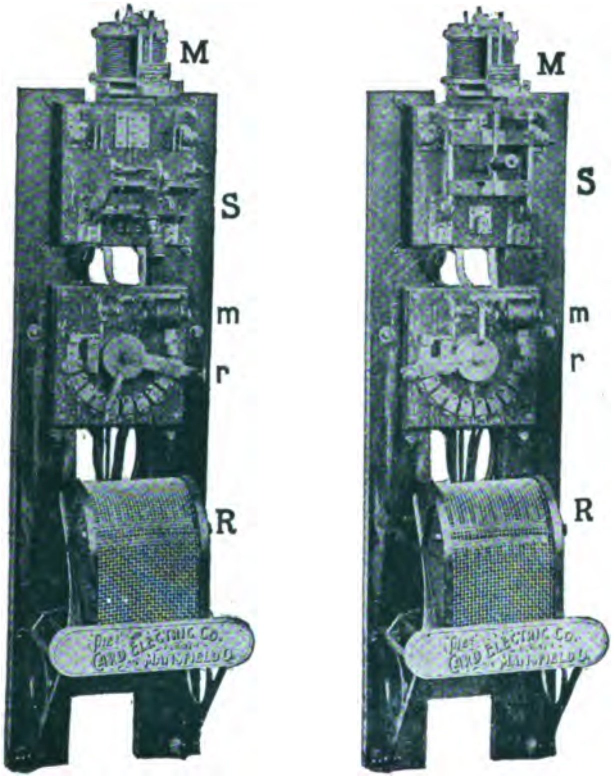


Fig. 306—Card Electric 5-H. P. Multipolar Motor.

The General Electric Company's moderate-speed, quadripolar motors are outlined in Fig. 308. The dimensions of these machines are given in the accompanying table. These machines correspond to the generators of the same type described in connection with Fig. 47.

The corresponding sizes for the General Electric Company's slow-speed motors are given in the lower part of the table on page 439.



Off. On.

Fig. 307—Controlling Apparatus of Card Electric Motor.

A motor controlling panel of the General Electric Company is represented in Fig. 309. These panels are employed for motors up to 15 H. P. in capacity. Above this size other panels are employed. The panel shown on the left-hand side is for motors operated on circuits of less than 300 volts pressure and employs fuse-wire cut outs at ff. The panel on the

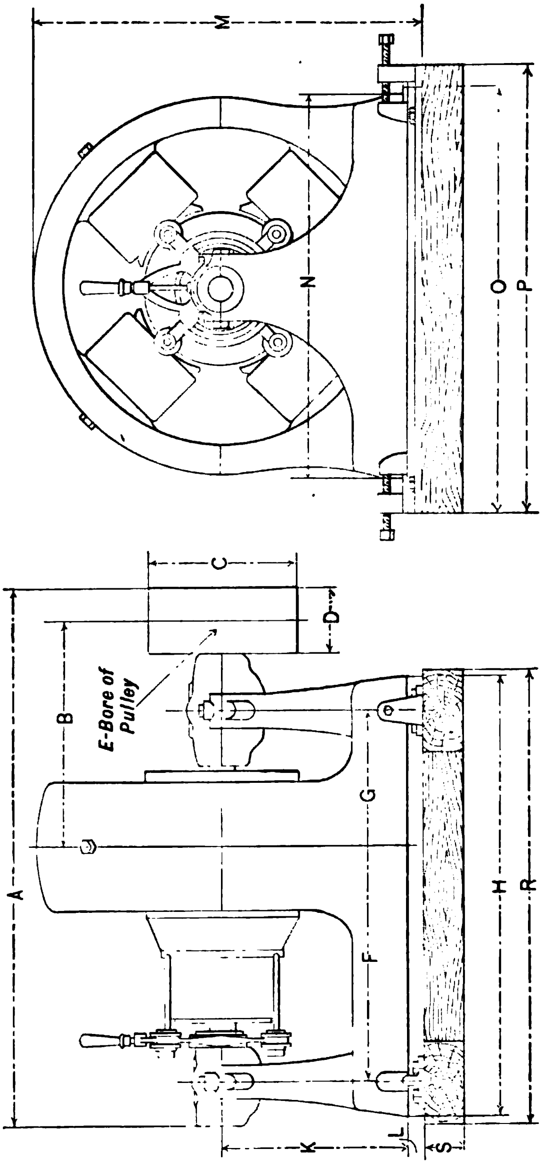


Fig. 308.—"General Electric" 4 Pole Generators and Motors.

GENERAL DIMENSIONS OF GENERAL ELECTRIC MOTORS—FORM H. MODERATE SPEED.

CLASSIFICATION.						WEIGHT.														RAILS—O. WOOD BASE FRAME.						
Type.	Poles.	H. P.	Speed. Volts. *125	Speed. Volts. 110-220	Form.	With Rails.	Without Rails.	A	B	C	D	E	F	G	H	K	L	M	N	Length.	Symbol.	P	R	S	Symbol.	KEYWAY.
MP	4	10	1400	1300	H	1,035	970	38 5/16	16⅛	8¼	5	1⅜	16½	10¾	31¾	12	1⅜	25⅝	26	34¾	AD 17	36⅛	34¼	3	CH 42	3" x ⅜" x 3/16"
MP	4	15	1300	1210	H	1,460	1,370	42⅞	18⅝	8¾	7	1¾	17¼	11¾	34½	13⅞	1½	29¼	30	39	AD 18	40¼	36	3	CH 44	3¾" x ½" x ¼"
MP	4	20	1100	1025	H	1,955	1,860	49⅞	21⅜	10½	9¼	2	19⅞	13⅛	39	15½	1½	32¼	33	43½	AD 19	43½	40	3	CH 45	5¾" x ½" x ¼"
MP	4	30	1050	975	H	2,610	2,500	57⅜	25	11	10	2⅛	22¼	15¼	44¼	16¾	1½	35	36	44½	AD 20	46¼	44¼	3	CH 46	6 1/16" x ½" x ¼"
MP	4	35	975	910	H	4,110	3,960	60⅞	26¾	11¾	11¼	2¼	22¾	15¾	45½	18½	1⅝	38⅝	40	52	AD 21	53	48½	4	CH 47	6¼" x ½" x ¼"
MP	4	50	900	840	H	5,080	4,920	69⅛	29⅞	14¾	13¾	2¾	26⅜	18⅜	52¾	22½	1⅝	46⅛	46½	55	AD 22	58¾	54¾	4	CH 48	8" x ⅝" x 5/16"
MP	4	65	850	790	H	7,325	6,150	72½	32⅛	15¾	16¾	3⅛	25⅞	18½	52⅞	24	1⅝	49	50¾	60½	AD 23	63	54⅜	6	CH 49	11" x ¾" x ⅜"
MP	4	75	800	745	H	7,410	7,200	78¾	33⅛	16¾	18¾	3¼	29¾	18⅞	57⅜	25	1¾	51¾	53	62¾	AD 24	65¾	58⅝	6	CH 50	12¼" x ¾" x ⅜"
MP	4	95	700	665	H	8,435	8,190	91¼	39	19¼	23	3⅞	34¼	19¾	63½	27	2	56	56	65½	AD 26	68¼	64	6	CH 51	16¼" x 1" x ½"

GENERAL DIMENSIONS OF SLOW-SPEED MOTORS—FORM H.

CLASSIFICATION.						WEIGHT.														RAILS—O. WOOD BASE FRAME.						
Type.	Poles.	H. P.	Speed. Volts. *125	Speed. Volts. 110-220	Form.	With Rails.	Without Rails.	A	B	C	D	E	F	G	H	K	L	M	N	Length.	Symbol.	P	R	S	Symbol.	KEYWAY.
MP	4	7	900	840	H	1,035	970	38 5/16	16⅛	8½	5	1⅜	16½	10¾	31¾	12	1⅜	25⅝	26	34¾	AD 17	36⅛	34¼	3	CH 42	3" x ⅜" x 3/16"
MP	4	10	850	790	H	1,460	1,370	42⅞	18⅝	9	7	1¾	17¼	11¾	34½	13⅞	1½	29¼	30	39	AD 18	40¼	36	3	CH 44	3¾" x ½" x ¼"
MP	4	15	800	745	H	1,955	1,860	50	21⅜	9½	9½	2	19⅞	13⅛	39	15½	1½	32¼	33	43½	AD 19	43½	40	3	CH 45	5¾" x ½" x ¼"
MP	4	20	700	650	H	2,610	2,500	57⅜	25	11	10	2⅛	22¼	15¼	44¼	16¾	1½	35	36	44½	AD 20	46¼	44¼	3	CH 46	6 1/16" x ½" x ¼"
MP	4	25	650	610	H	4,110	3,960	61⅛	26¾	11¾	11¾	2¼	22¾	15¾	45½	18½	1⅝	38⅝	40	52	AD 21	53	48½	4	CH 47	6¼" x ½" x ¼"
MP	4	35	600	560	H	5,080	4,920	68⅝	29⅞	17¼	12¾	2¾	26⅜	18⅜	52¾	22½	1⅝	46⅛	46½	55	AD 22	58¾	54¾	4	CH 48	8" x ⅝" x 5/16"
MP	4	50	550	515	H	7,325	6,150	72¾	32⅛	18⅜	17¼	3⅛	25⅞	18½	52⅞	24	1⅝	49	50¾	60½	AD 23	63	54⅜	6	CH 49	11" x ¾" x ⅜"
MP	4	60	550	515	H	7,410	7,200	79⅜	33⅛	18¾	20	3¼	29¾	18⅞	57⅜	25	1¾	51¾	53	62¾	AD 24	65¾	58⅝	6	CH 50	12¼" x ¾" x ⅜"
MP	4	85	500	470	H	8,435	8,190	91¾	39	20¾	24	3⅞	34¼	19¾	63½	27	2	56	56	65½	AD 26	68¼	64	6	CH 51	16¼" x 1" x ½"

* Same Speed for 250 and 500 Volts.

right-hand side is for pressures above 300 volts, and employs magnetic fuse-holders at F, F. These panels are 32 inches high and 14 inches wide. The supply mains are connected to the terminals p and n. The armature terminals to a a, and the shunt field terminal to s. The connections are illustrated in Fig. 310. It will be observed that the double-

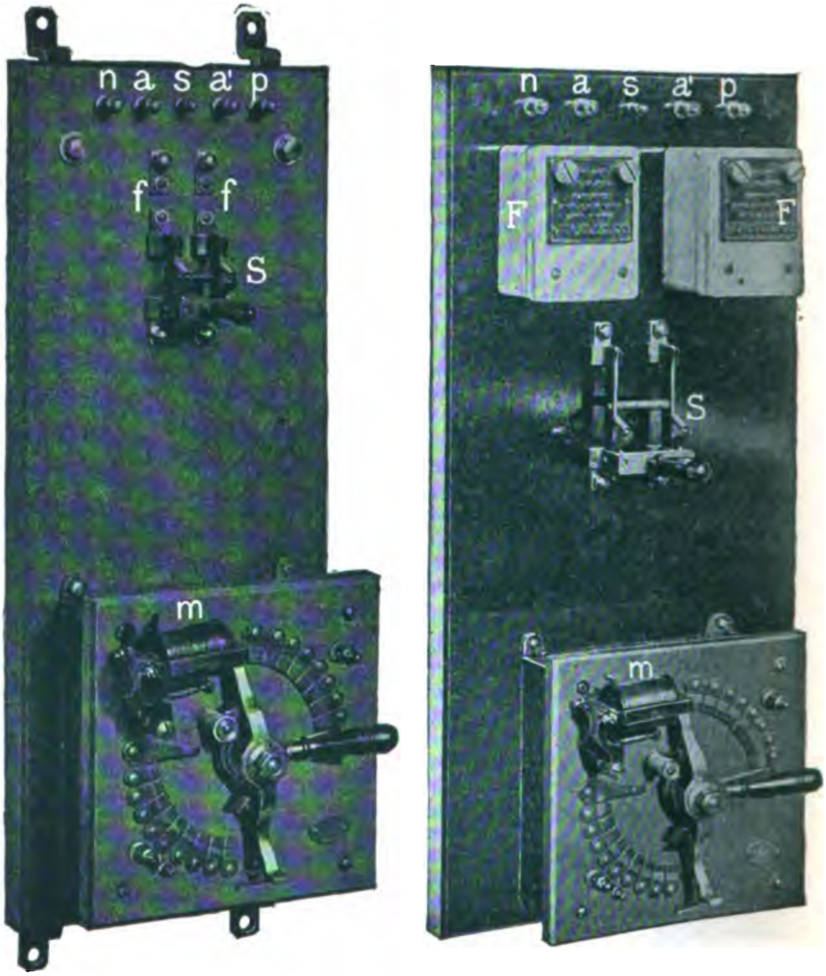


Fig. 309—General Electric Small Motor Controlling Panels.

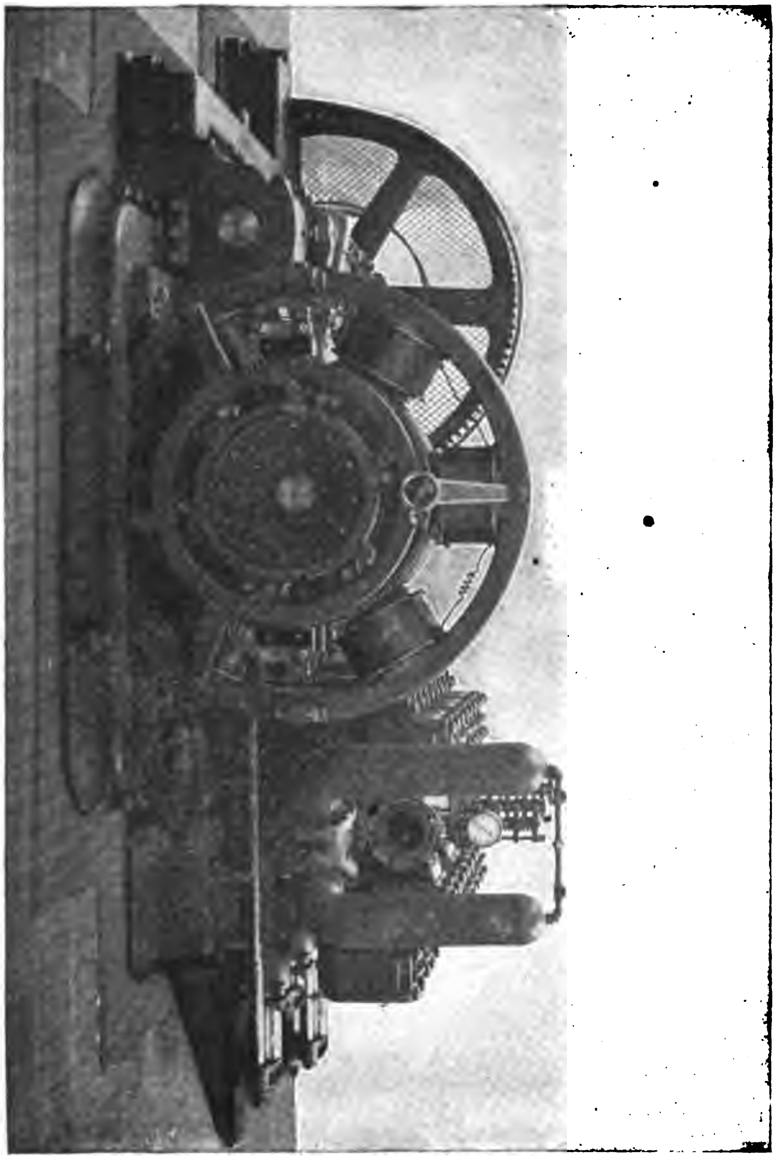


Fig. 311—General Electric Motor Driving Deep Mine Pump.

pole switch S, brings the pressure to the rheostat terminals. On turning the handle clockwise, the shunt field circuit is first closed. The armature circuit is then closed through resistance. The resistance is then cut out slowly until, when the motor is at full speed, all extra resistance is cut out, and the handle is locked by a detent under control of the magnet. Either an excess or an interruption of current will release the handle, which then returns to the normal position.

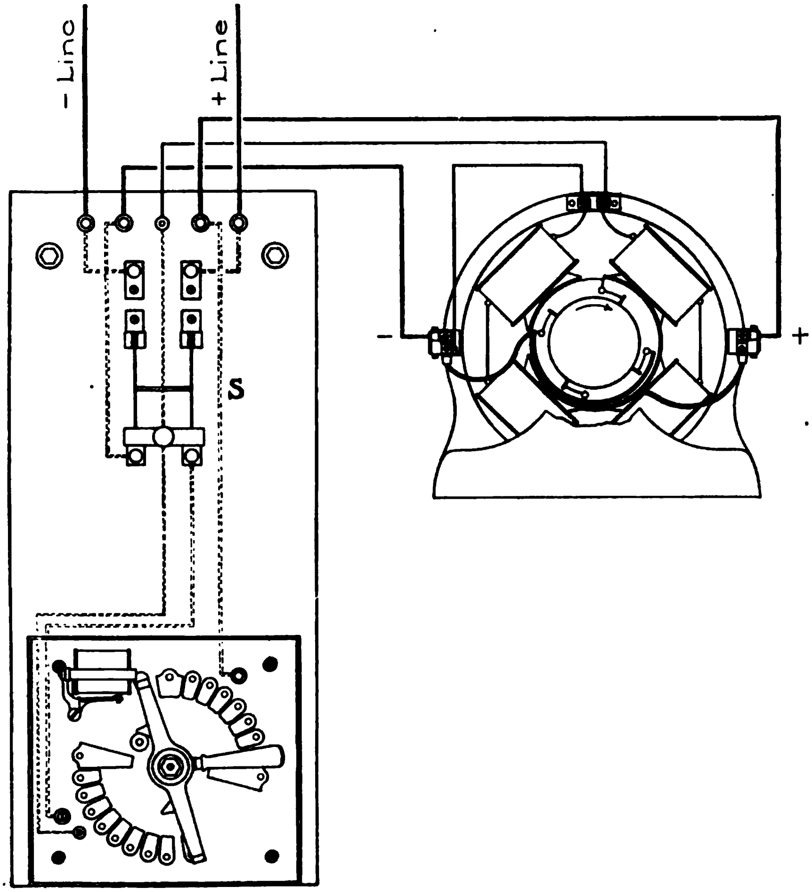


Fig. 310.—Connections for General Electric Motor Starting Panel.

Fig. 311, shows a General Electric Company's six-pole 100 H. P. continuous-current motor driving a deep-mine pump at 250 revolutions per minute, with a capacity of 500 gallons per minute under 550 feet head.

Fig. 311 A, shows a front view, and Fig. 311 B, a rear view, of a type of continuous-current fan motor of the General Electric Company. The extension tubes on the back hold two carbon brushes resting on opposite sides of a commutator within. These fans are suitable for connection to an incandescent lighting circuit at, say, 110 volts pressure.

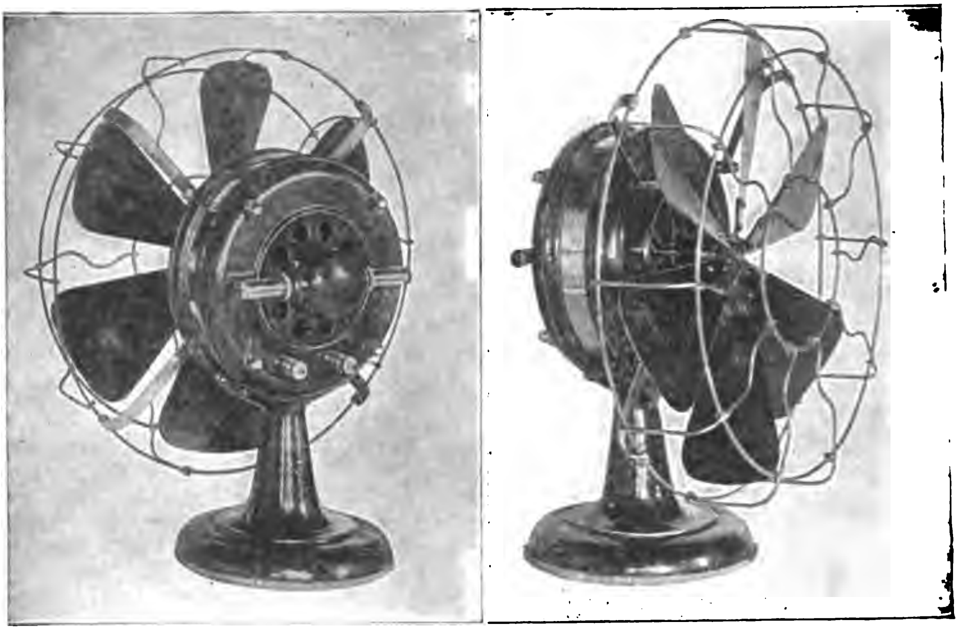


Fig. 311 A. Fig. 311. B.

Front and Rear View of "General Electric" Continuous-Current Fan Motor for Incandescent Lighting Circuits.

The parts of a 20-H. P. Westinghouse Electric Company's continuous-current motor, are shown in Fig. 312. The armature is of the iron-clad type. There are four poles and four carbon brushes. There are four terminals, two for the field,

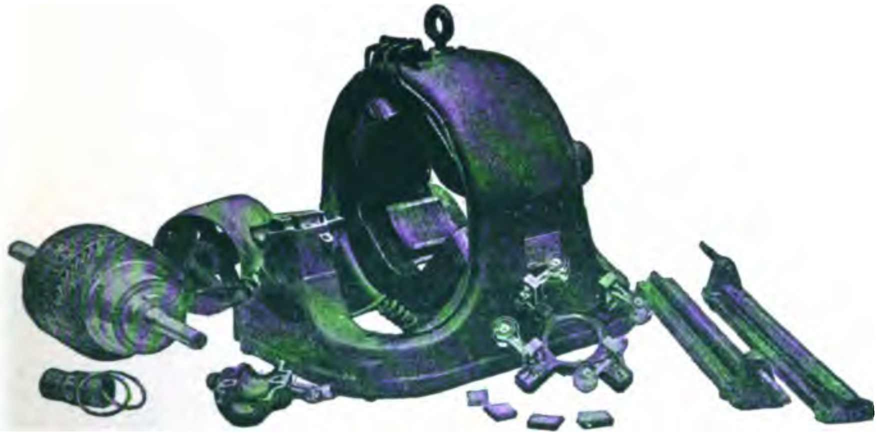


Fig. 312—Parts of Westinghouse 20-H. P. Motor.

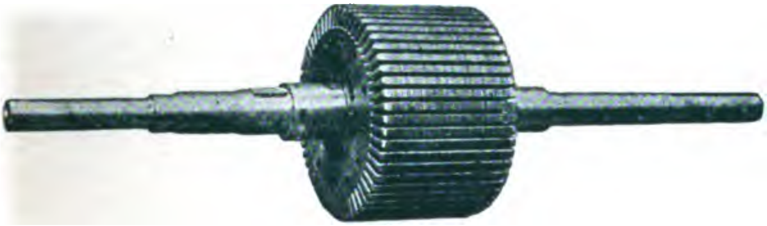


Fig. 313—Armature Core of Westinghouse 15-H. P. Motor.

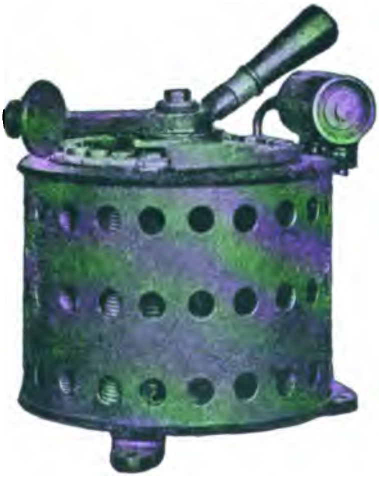


Fig. 314—Westinghouse Starting and Automatically Releasing Rheostat.

and two for the armature. Fig. 313, shows the armature core of a 15 H. P. motor. The dimensions of these machines have been given on page 83, in connection with the Westinghouse Company's generators.

Fig. 314, shows a Westinghouse starting and automatically releasing rheostat. The small magnet shown holds the contact lever in position, after the motor has been brought up to speed.

Fig. 315, shows a Sprague-Pratt elevator hoisting machine. A motor M, coupled directly to a screw shaft, drives this shaft through a nut N, which is attached to a cross-head carrying the movable sheave V. When the elevator car has to be lifted, the motor is driven so as to pull the movable sheave V, away from the fixed sheaves V, and thereby slowly haul upon the ropes R. The end view of the sheave is shown at V′, V′, and the end view of the motor at B′. B, is a brake mounted over a cylinder on the motor shaft, and held down by a spiral spring s, opposed by an electro-magnetic coil m. If no current passes through the coil m, the brake is applied by the action of the spiral spring s, and the passage of the current through the magnet m, removes the brake. G, is a centrifugal governor, so arranged that if the speed of the armature exceeds a certain limit, lower than the limit of the centrifugal governor attached to the car, the motor will be brought to a stand-still. S, is a limit stop, so arranged that the motor will be stopped by the roller r, of the movable sheaves, striking a switch, and thereby interrupting the motor armature-circuit. This would occur should the motor overrun or carry the sheaves dangerously near the upper limit, corresponding to a dangerously high position of the car in its shaft. S′, is a similar limit stop, which is brought into connection when the movable sheaves approach the other end of the screw too closely. To raise the elevator, power is applied by the motor. When the elevator descends, it drives the motor and causes it to act as a generator. The circuit at the lower stop S′, is normally open, but on being struck by the movable sheaves the circuit is closed at S′, and short-circuits

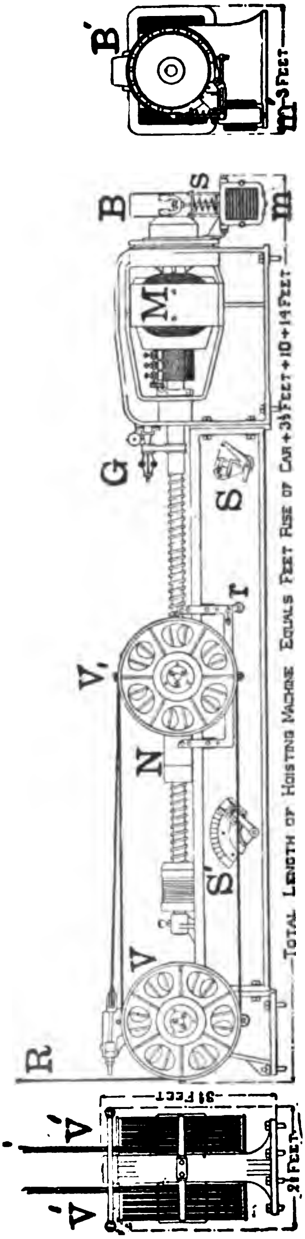

B'
III
3 FEET
B
S
III
M
G
S
I
V,
N
S'
V
R
TOTAL LENGTH OF HOISTING MACHINE EQUALS FEET RISE OF CAR + 3½ FEET + 10 + 14 FEET
3½ FEET
2½ FEET
V'
V'

Fig. 315—Sprague-Platt Electric Elevator.

the motor armature through a suitable resistance, thereby exerting a powerful drag upon the motor armature which tends to arrest its further progress.

A longitudinal section of the nut N, is shown in Fig. 316. It will be seen that the screw thread presses upon the wards of the nut through a number of steel balls which form an endless chain around the screw shaft. By this means the friction of the screw is greatly reduced. A safety nut is also provided for releasing the cross head from longitudinal movement in case of accidental derangement.

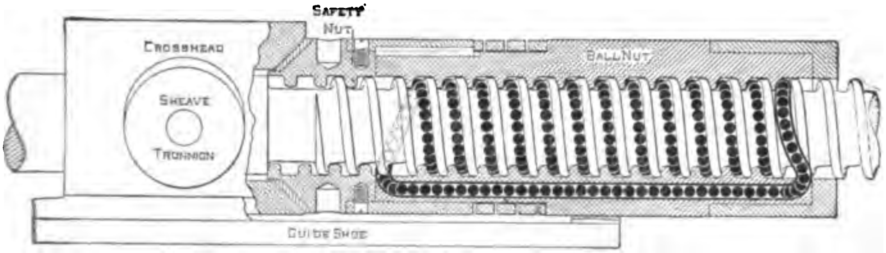


Fig. 316—Longtitudinal Section of Nut of Sprague-Platt Elevator Hoist.

Fig. 317, shows a switchboard for the control of a Sprague-Pratt elevator car. R, is a rheostat contact-plate provided with two sets of coils and contacts, and with a contact arm moved by a small motor, called a *pilot motor*. s, is a pair of magnet coils acting upon a circuit-closing device, and called a short-stop. S, is a main double-pole switch which is magnetically held in position when closed ; h, is the handle of a car controller switch for operating the car from the switchboard ; t, is a throttler coil, and k, a brake-releasing coil ; B and b, are the main and auxiliary circuit-breakers. The car of the elevator is provided with a controller switch like that at h. V, is a throw-over switch for delivering the control of the car from the handle h, to the similar handle on the car. These handles have three contacts, one for going up, one for coming down, and the third for stopping. The contacts effected at the car controller switch, operate the pilot motor and the short-stop s. The pilot motor rotates the arm of the rheostat contact switch, and regulates the supply of current through the armature of the hoisting motor. It also effects contacts which close the circuits of the coils and circuit breakers B and b. Thus, when the operator on the car

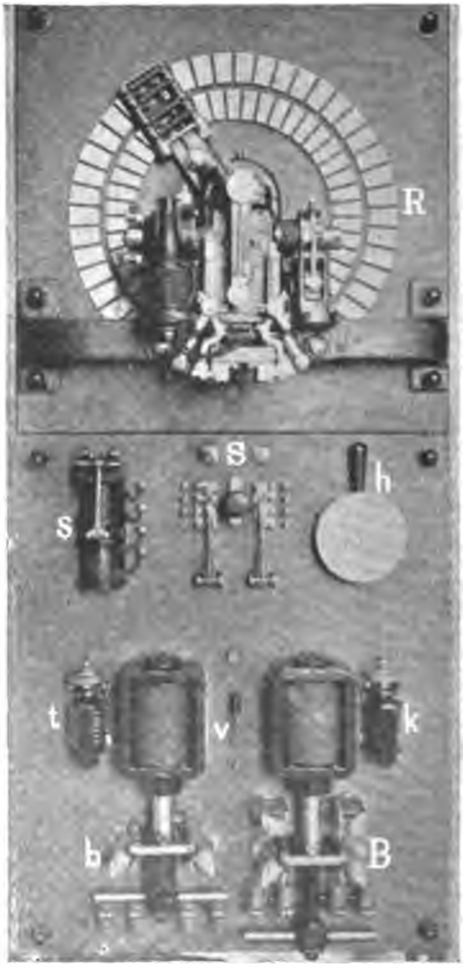


Fig. 317—Sprague-Platt Electric Screw Elevator Switchboard, Pilot Motor Main Resistance and Pilot Switch.

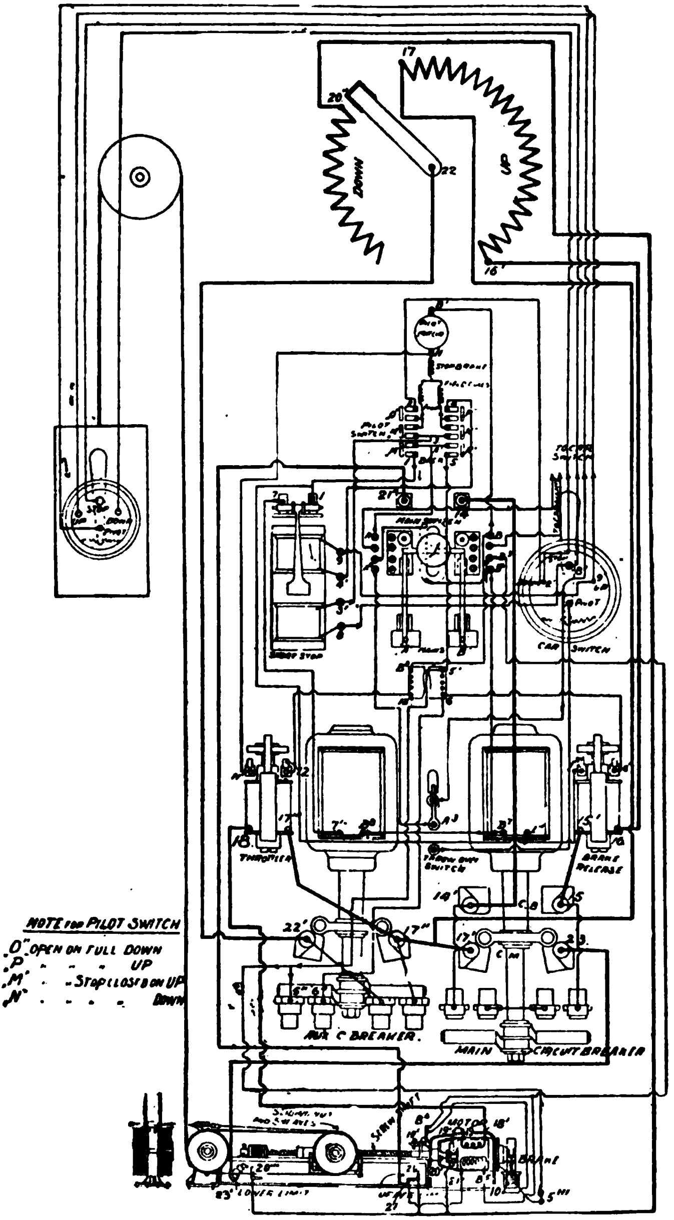


Fig. 318—Diagram of Connections and General Arrangements, Sprague-Pratt Electric Elevator.

presses his up-contact, this causes the pilot motor to revolve and effect a contact at the rheostat arm shaft. This contact causes the contact breaker B, to be operated closing a circuit which in its turn allows the main circuit current to flow through the hoisting motor.

Various safety devices for automatically controlling the speed and position of the car are employed.

The detailed connections of the switchboard are shown in Fig. 318. Fig. 319, shows a triple-deck Sprague-Pratt elevator machine, employed in the Commercial Cable Building, New York City.

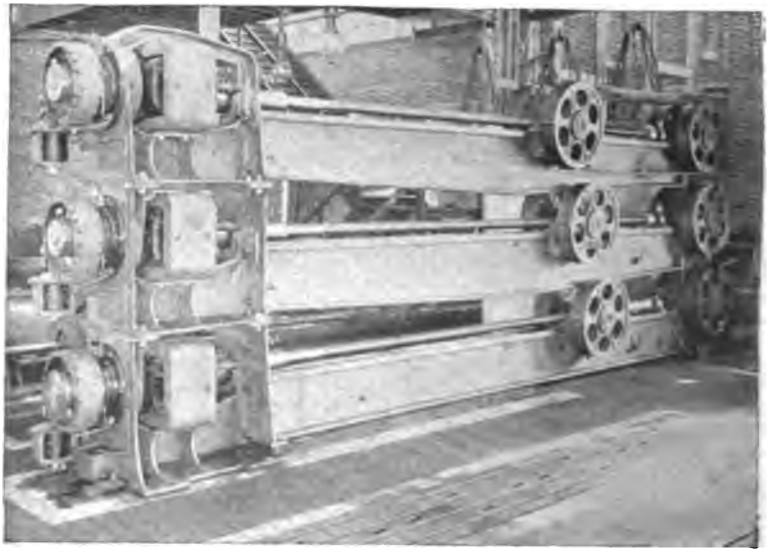


Fig. 319—A Triple Deck Sprague-Pratt Electric Elevator Machine.

Fig. 320, shows the Bullock Electric Company's quadripolar belt-driven generator or motor, of 100 K. W. capacity. It is wound for 125, 250, or 500 volts pressure at 500 revolutions per minute, and is compounded. The series coils are placed on the pole-tips, and are separated from the shunt coils by a ventilating space. There are four sets of carbon brushes. Each brush is clamped between a pair of brass plates, one of which is metallically connected to the brush-holder bar by a flexible conductor. The pole-pieces are made up of plates, about $\frac{1}{8}$ inch thick, cast into the field frame. The position of the brushes is not changed under any condition of load. The temperature elevation claimed for these machines, as a maximum after five hours full load, is 39°C (70°F) for any part of the machine except the commutator. The pulley is made of paper.

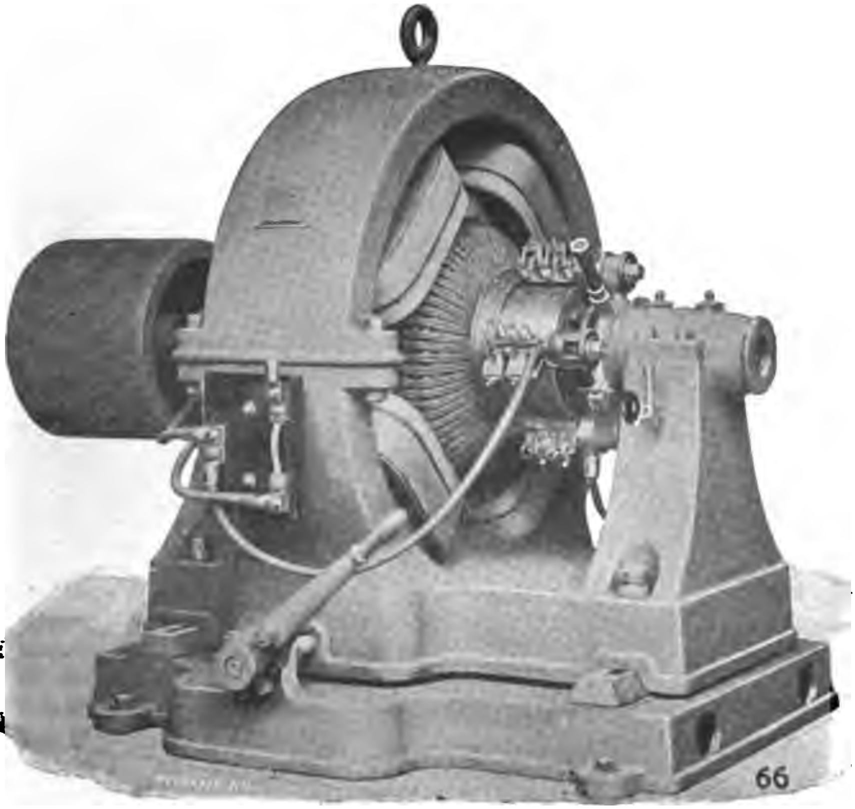


Fig. 320—Bullock Electric Quadripolar Belt-Driven Generator or Motor.

The following table shows the sizes of these machines, wound for slow speed, and rated as generators.

DIMENSIONS OF BULLOCK ELECTRIC COMPANY'S SLOW-SPEED BELT-DRIVEN GENERATORS AND MOTORS.

Classification				Volts.	Amperes.	Pulley.	
Type.	Poles.	K. W.	Speed.	Full Load.	Full Load.	Diam. in Inches.	Face in Inches.
E	4	1	1200	125-250-500	8- 4- 2	6.5	2.5
E	4	2	1150	125-250-500	1-6 8- 4	6.5	2.5
E	4	3	1100	125-250-500	24- 12- 6	7	3.5
H	4	4.5	1000	125-250-500	36- 18- 9	9.5	4
H	4	7	900	125-250-500	56- 28- 14	10.5	5.5
H	4	9	800	125-250-500	72- 36- 18	12	7.5
H	4	12.5	725	125-250-500	100- 50- 25	13	8
H	4	17.5	675	125-250-500	140- 70- 35	14	10
H	4	25	650	125-250-500	200-100- 50	15	12
H	4	35	600	125-250-500	280-140- 70	16	16
H	6	50	575	125-250-500	400-200-100	16.5	20
H	6	75	500	125-250-500	600-300-150	23	24
H	6	125	450	125-250-500	1000-500-250	27	28
H	8	175	435	125-250-500	1400-700-350	34	36

Fig. 321, shows a Bullock Electric Company's type "E." quadripolar slow-speed motor, suitable for direct connection to line shafting.

Fig. 322, shows the armature core of the Bullock electric motors. The grooves are vertical, and there are ventilating ducts as shown. The conductors are covered and held in place by wooden strips, which are inserted in grooves near the surface of the teeth, so that the wires are completely encased in wood and in mica.

The commutator bars are of drop-forged copper.

Fig. 323, shows a Bullock Electric Manufacturing Company's enclosed type "E" quadripolar motor, suitable for direct connection to machines, tools, etc. The field and armature are enclosed, only the commutator and carbon brushes being left exposed to view. These machines are wound for 125, 250 or 500 volts, and are designed for slow speeds.

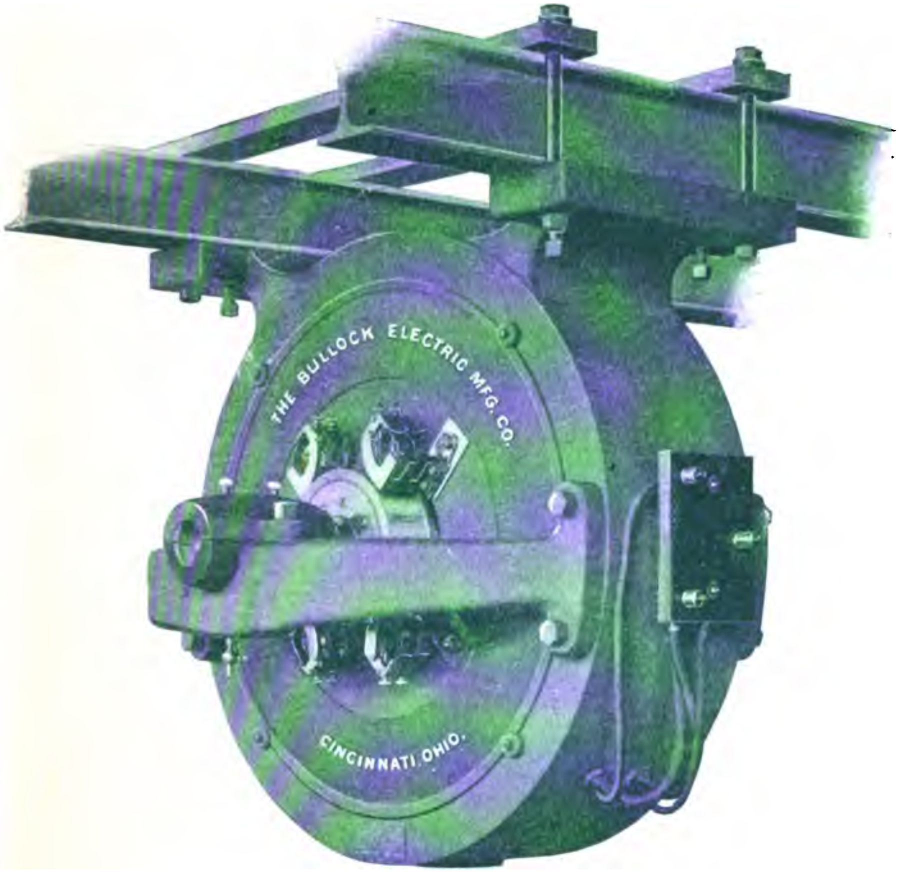


Fig. 321—The Bullock Electric Type "E" Quadripolar Motor.

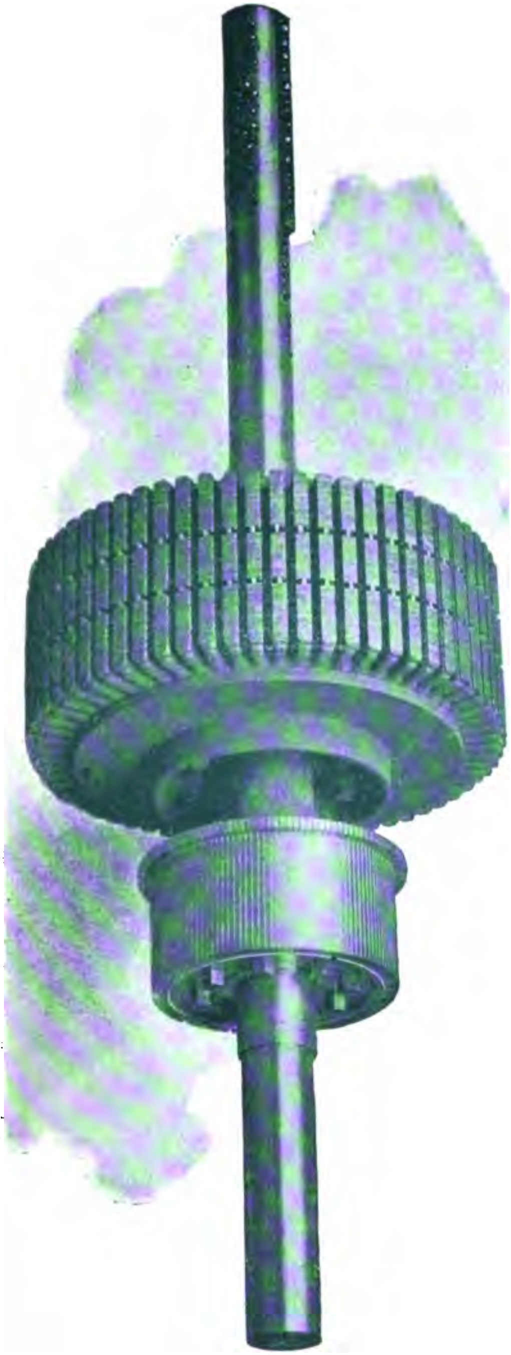


Fig. 322—Armature Core of Bullock Electric Motor.

A Bullock Electric Company's slow-speed quadripolar motor mounted directly on a lathe, is shown in Fig. 324.

This motor has five speeds, both forward and backward, under the control of the handle c, which operates a controller.

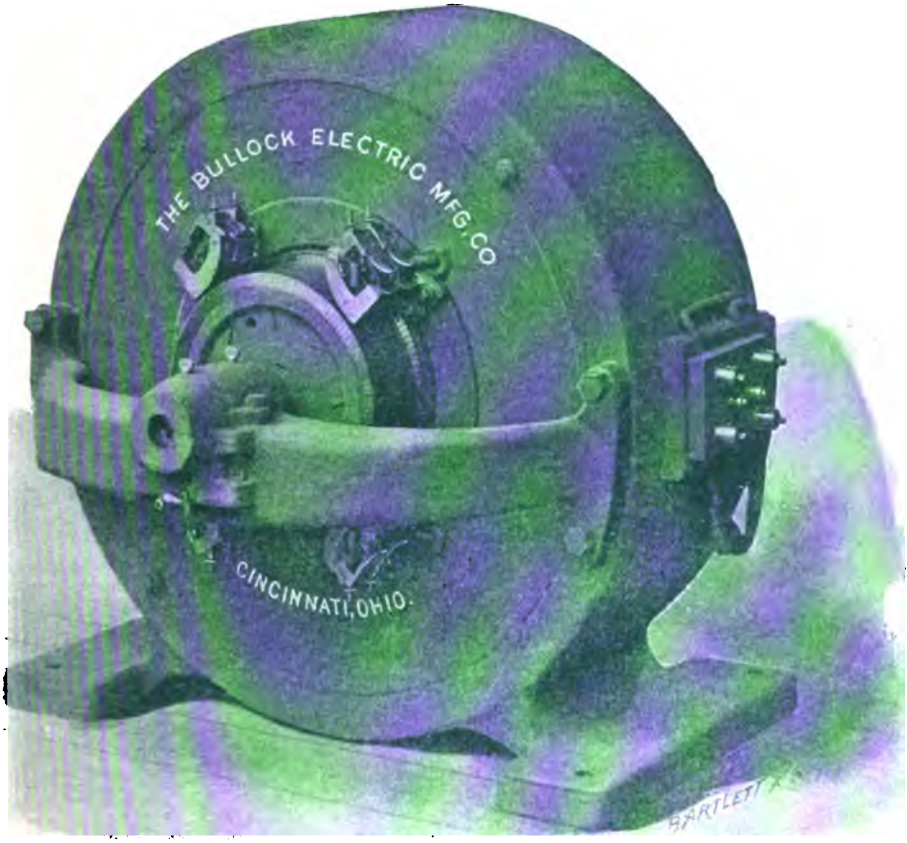


Fig. 323—Bullock Electric Enclosed Type "E" Quadripolar Motor.

The motors are operated on either 125 or 250 volt circuits, and are compound-wound. A 22-inch lathe runs at five speeds between 160 and 290 revolutions per minute.

When the handle c, is in its central position, the motor is stopped. When the handle is raised, the motor runs in one direction at a speed determined by the degree of elevation given to the handle. When the handle is lowered, the direction of rotation is reversed. The position of the controller handle by the side of the bed-plate makes the control of the lathe very convenient for the workman.

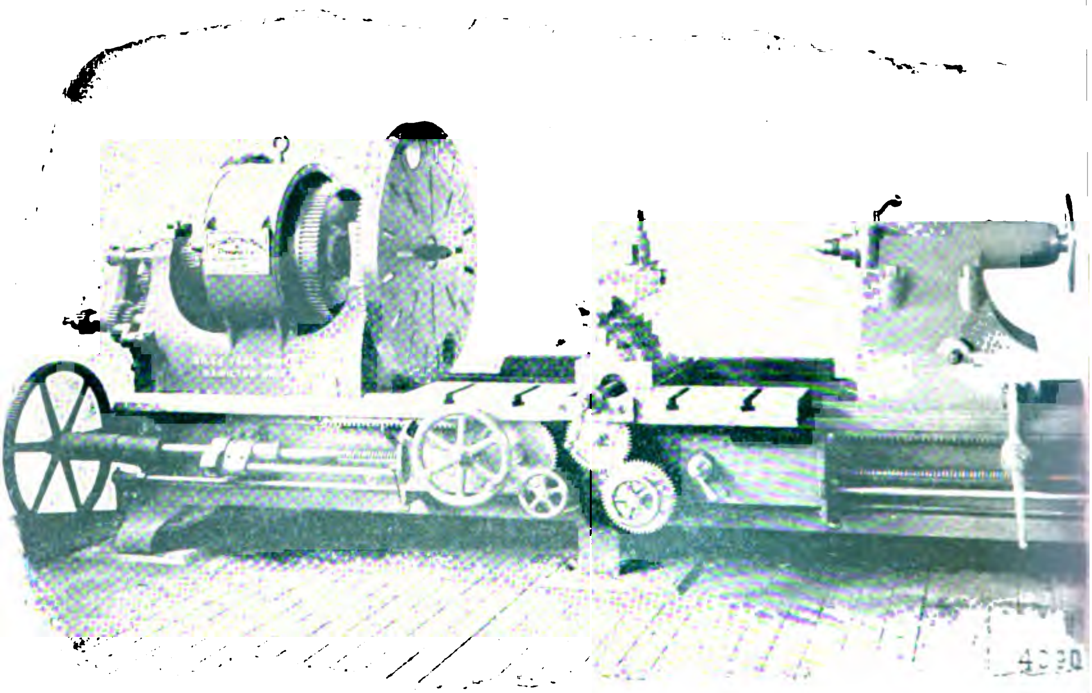


Fig. 324—Bullock Electric Motor, Directly Connected to Lathe.

Fig. 325, shows a " Bullock " Electric Company's enclosed type of motor, coupled directly to the driving shaft of a printing press. This machine has five speeds in the forward direction between 100 and 170 revolutions per minute, and one speed backwards. A mechanically applied brake is shown, for rapidly bringing the machine to rest, when desired.

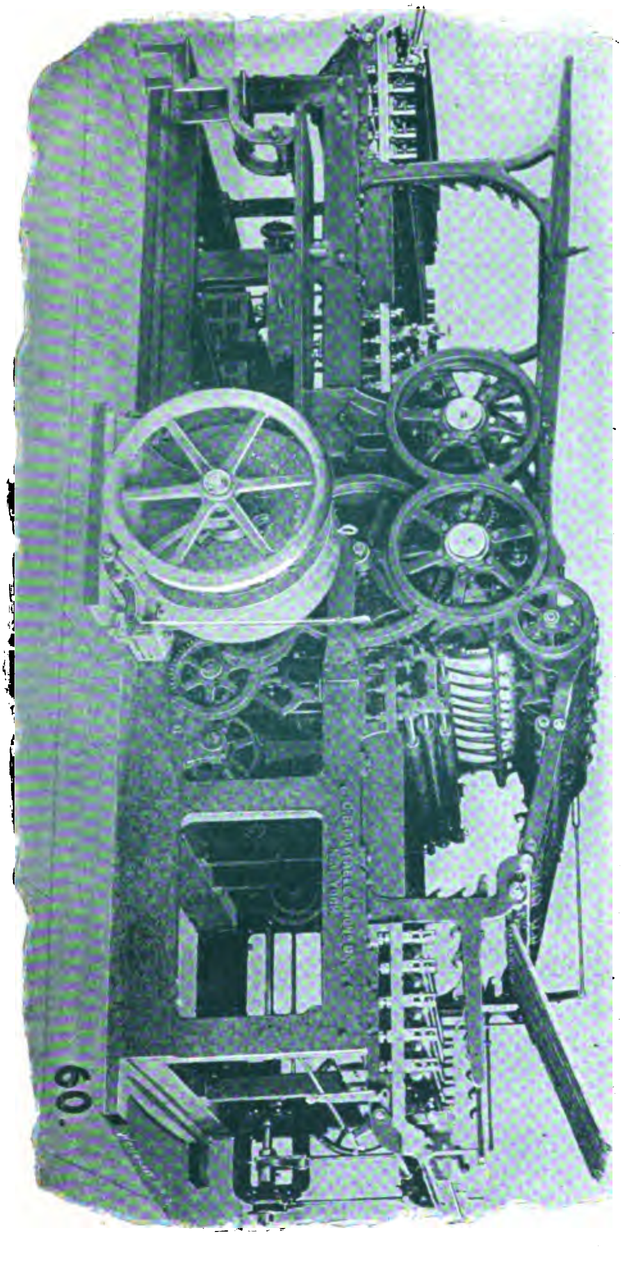


Fig. 325—Bullock Electric Motor Directly Connected to Printing Press.

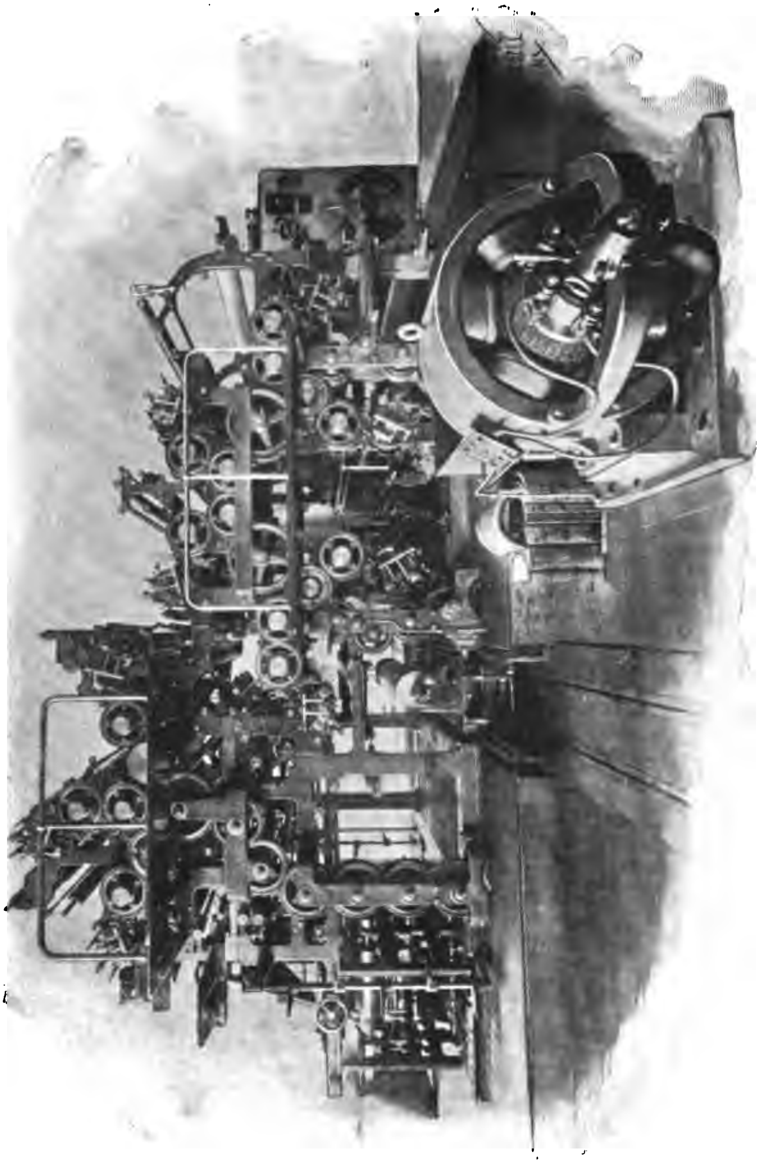


Fig. 226.

Fig. 326 shows a sextuple printing press similarly operated.

In most of these machines, release magnets in the controller-case are operated by push contacts placed at different points round the press, so that the operator may readily stop the press from any place in which he may stand by it.

CHAPTER XI.

LOCOMOTORS

THE electric motors which we have hitherto considered, are stationary motors. Probably, the most extensive use of electric motors at the present day is for street-railway cars, or for purposes where the motor is moved, i. e., is a *locomotor.* Although, of course, the general construction is the same for locomotors as for stationary motors, yet the conditions of operation are necessarily much more severe in the former than in the latter, and this has led to such differences in details of construction, that the locomotors are preferably treated as a separate class. The severe conditions to which locomotors are often necessarily subjected, have resulted in a marked improvement in the mechanical development of electric motors generally, since many of the methods which were found successful in enabling the street railway motor to defy dust and moisture have been introduced into the stationary motor with marked success.

Figs. 327 and 327 A, show a Walker Company's 25 H. P. street-car motor. The equipment of a standard electric street-car motor commonly consists of two 25 H. P. motors, one connected with each of the car axles. The necessity of providing 50 H. P. for the propulsion of such a car is evident when the speeds, loads, and grades are considered, with which the electric street-car is expected to cope.

The motor is constructed in two main parts, the upper frame, and the lower frame. These are hinged together at one side, and are held together at the other by the eye-bolts B B. The steel shell so formed completely encloses the

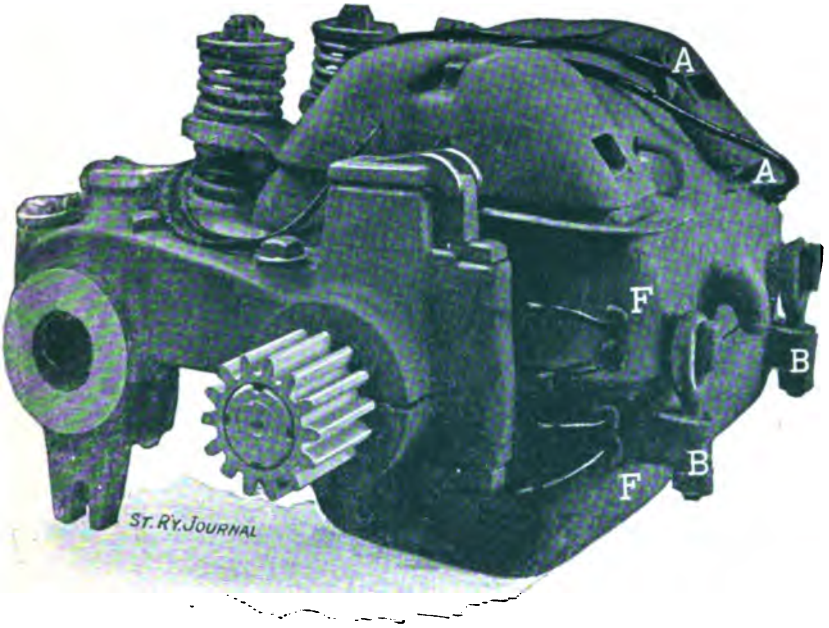


Fig. 327—Walker Company's "Short" Railway Motor—Walker & Co.

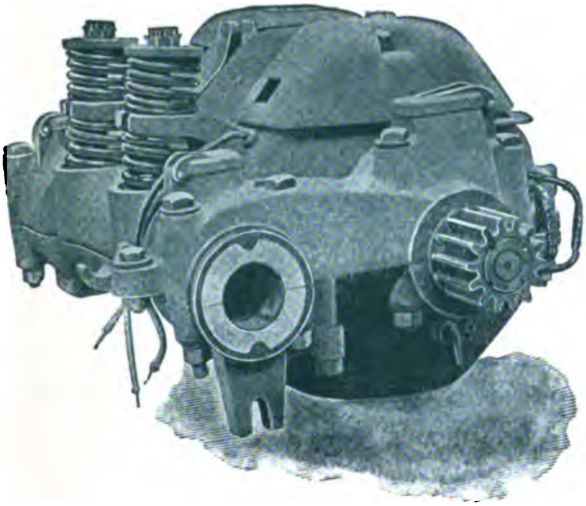


Fig. 327 A—Walker Company's "Short" 25 H. P. Street Car Motor.

working parts of the motor, leaving only the pinion projecting as shown, at the end of the armature shaft.

The interior of the motor, when the upper frame is removed, is seen in Fig. 328.

Here the iron-clad armature, of the barrel-wound type, is seen resting in its bearings in the lower frame, and with the commutator at one end and the projecting pinion at the other.

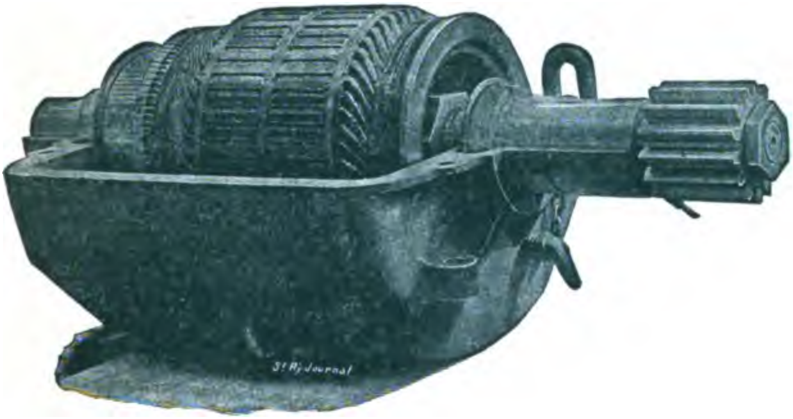


Fig. 328—Walker Company's "Short" Railway Motor with Upper Frame Removed.

Fig. 328 A, shows the interior of the upper frame. A field-coil is seen surrounding a field pole. Like nearly all street-car motors, the field-frame has four poles. The field cores are made as short as possible, to economize space and material. The ends of the field wires are seen projecting through the case, and are shown at F F, Fig. 327.

Fig. 329, shows the method of supporting the armature bearings outside the frame of the motor, in such a manner that all waste lubricant escaping from the bearings, falls by the outlet C, clear of the motor. The flanges on the shaft and in the frame prevent oil and dirt from entering the interior of the motor.

The method of mounting the Walker Company's motor in the car truck is illustrated in Fig. 329 A. It will be seen

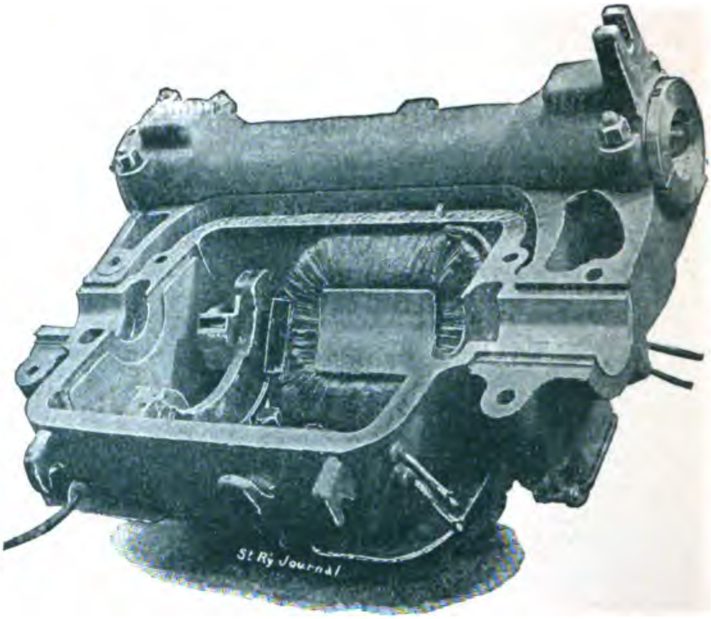


Fig. 328 A—Walker Company's "Short" Street-Car Motor—Upper Frame.

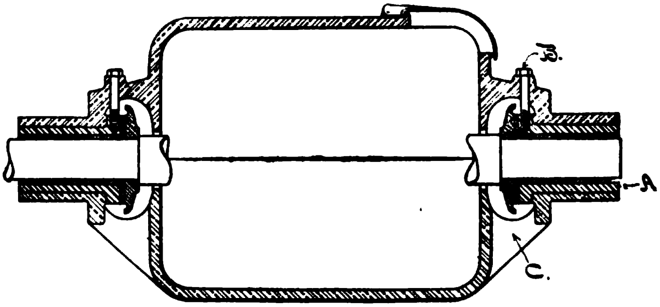


Fig. 329—Walker Company's "Short" Street-Car Motor and Bearings.

that the motor M is suspended on four spiral springs, two in front of it, and two behind. Flexibility in the support of a

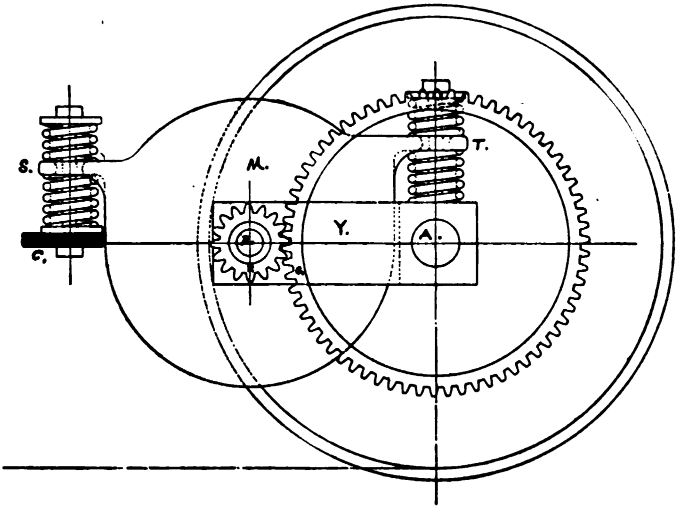


Fig. 329 A—Method of Mounting Walker Company's "Short" Motor in Car Trucks.

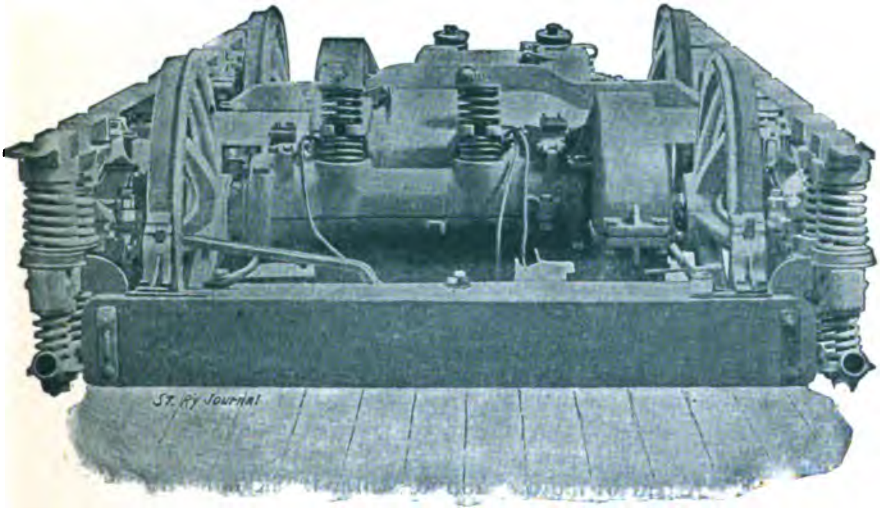


Fig 330—Walker Company's "Short" Motors Mounted in Truck.

street-car motor is always found to be essential, a rigid suspension bringing speedy destruction through inertia and vibration, when travelling over even a carefully levelled track. A pair of motors mounted in a truck is seen in Fig. 330.

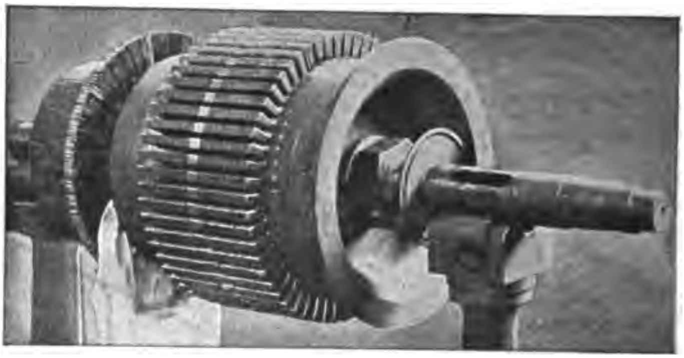


Fig. 331—Armature for Walker Company's 25 H. P. Street-Car Motor.

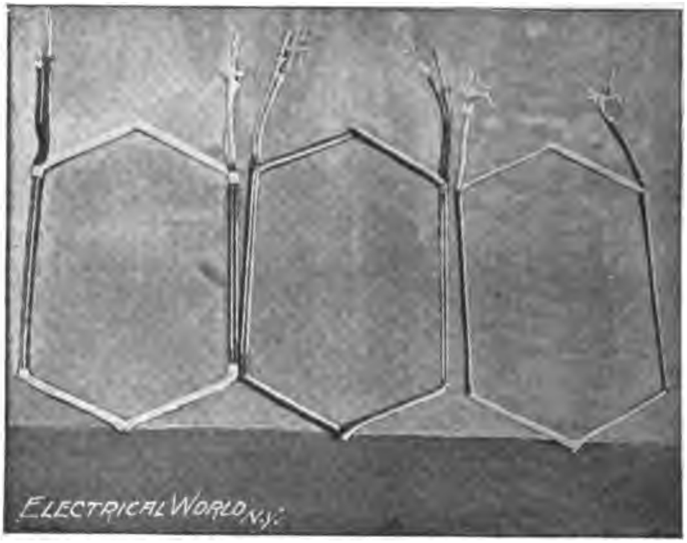


Fig. 332—Walker Company's "Short" Armature Coils.

The unwound armature of a Walker Company's 25 H. P.

motor is shown in Fig. 331. The flanges are seen at the ends which give protection to the winding.

Fig. 332, shows the formed armature coils ready for placing in the grooves, and Fig. 333, shows a bar-armature in process of winding. Street-car armatures are almost always wound for 500-volt continuous-current circuits, but the armature of Fig. 333, is intended for a reduced pressure supplied by storage batteries.

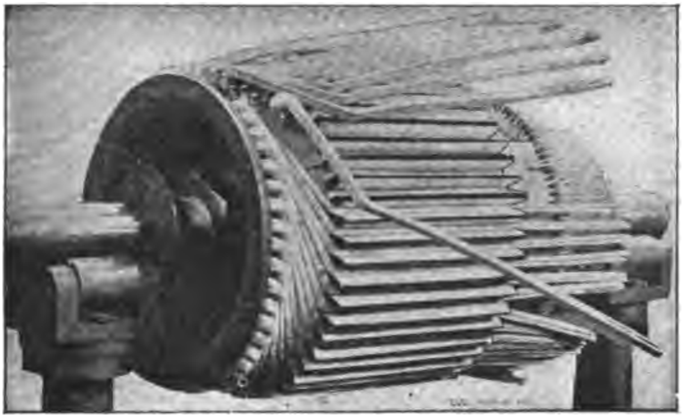


Fig. 333—Walker Company's "Short" Armature Winding.

Carbon brushes are always used for street-car motors and access is generally provided to them through a flap or hinged cover in the motor frame placed over the commutator, as seen A A, in Fig. 327.

Like all modern street-car motors, The Walker Company's motors are *single reduction motors;* i. e., the motor has but one set of gears between its shaft and the car axle, so that the motor is of comparatively slow speed. The horizontal efforts of the standard Walker motors are shown in the following table.

Thus, No. 2 pushes the car forward on level rails with a force of 700 pounds weight, when employing 33-inch car-wheels, and running at ten miles per hour.

STANDARD SIZES OF WALKER RAILWAY MOTORS.

TRADE NUMBER.	HORIZONTAL EFFORT.
2	700
3	800
4A	1000
10	2000
15	3000
20	5000

Fig. 333 A, shows the interior of the starting resistance, which is thrown into the armature circuit at starting, so as to check the flow of current until the motor has got under way. These starting resistances are constructed of strip iron, wound in flat coils, insulated by strips of asbestos.

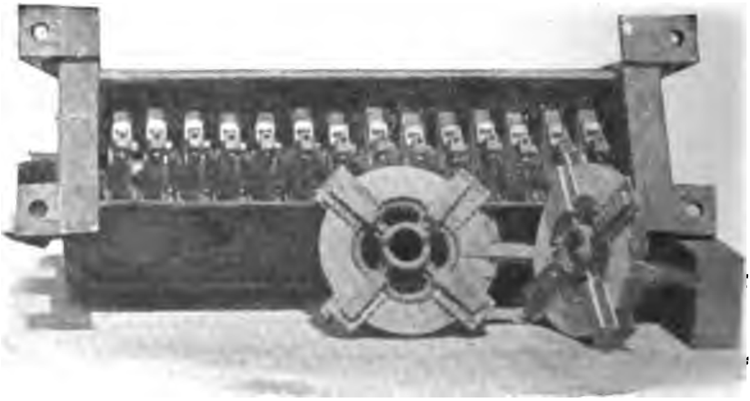


Fig. 333 A—Interior of Walker Company's Street-Car Motor.

The plan and interior of a Walker Company's controller is shown in Fig. 334. The main handle operates a contact cylinder; i. e., a cylinder carrying projections or fingers that close contacts at certain points in their revolution. These contacts connect the motors in series at starting and in parallel when running rapidly, besides effecting minor intermediate modifications in their speed. It has seven running positions. The smaller handle is called the reversing switch. It has also seven running points or positions. The first runs both motors forwards. The second runs both backwards. These are the only points in ordinary use. Should one

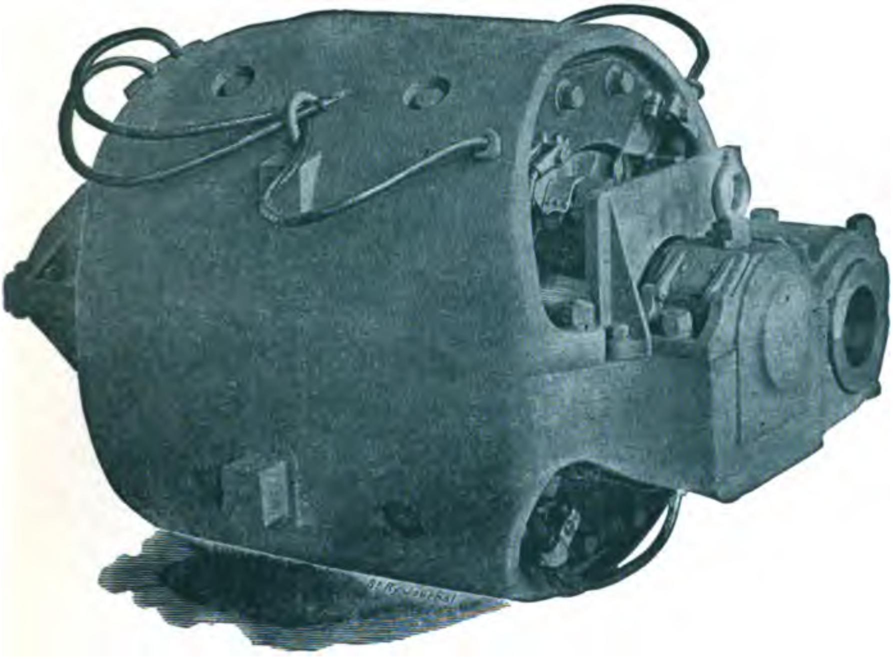


Fig. 335—Walker Company's "Short" 200 H. P. Railway Motor.

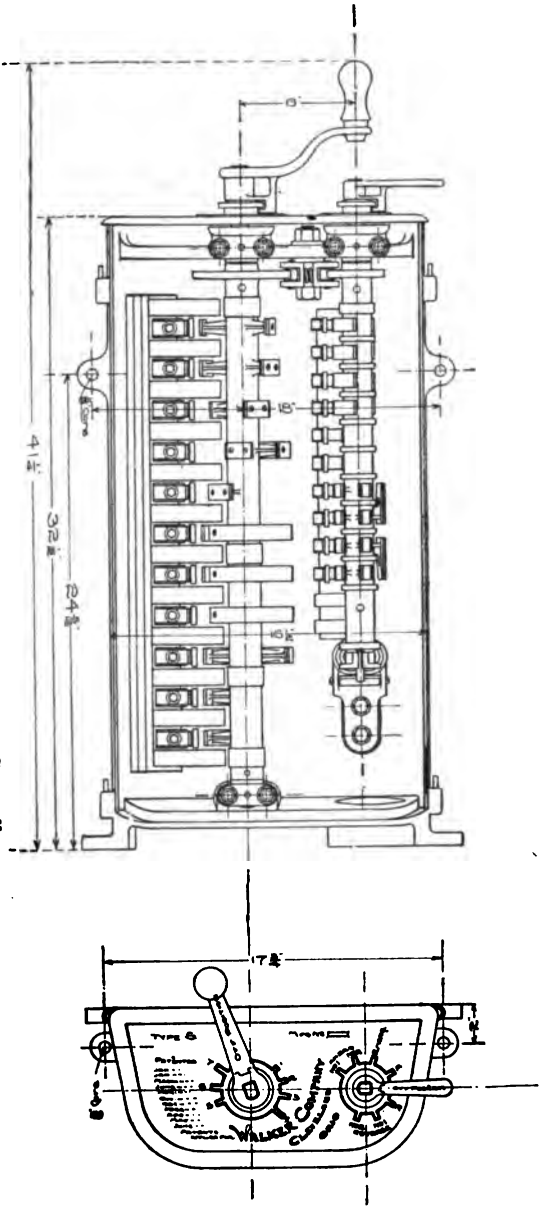


Fig. 334—Walker Company's Street-Car Controller.

The General Electric Company's "Terrapin Back," type of *electric mining locomotive* is shown in Fig. 338. These locomotives are working efficiently in a number of mines. The table of dimensions of these machines is as follows:—

TABLE OF SIZES AND CAPACITIES OF GENERAL ELECTRIC COMPANY'S "TERRAPIN BACK" ELECTRIC MINING LOCOMOTIVE.

No.	H. P.	Speed in Miles per hour.	Draw Bar Pull.	Minimum. Gauge.	Minimum Wheel Base.	Extreme Dimensions.			Diameter Wheels.	Weight.
						Width over all.	Length exclusive of Draw-Bars.	Total height from Top of Rail.		
			Lbs.	In.	In.	In.	Ft.	In.	In.	Lbs.
1	15	6	750	18	24	32	8	21	20	3,500
2	25	10	750	18	24	32	8	21	20	3,500
3	30	6	1,500	24	30	42	9–6	30	28	7,000
4	50	10	1,500	24	30	42	9–6	30	28	7,000
5	45	6	2,250	30	36	48	9–6	36	28	10,500
6	75	10	2,250	30	36	48	9–6	36	28	10,500
7	60	6	3,000	30	40	48	9–6	36	28	15,000
8	100	10	3,000	30	40	48	9–6	36	28	15,000
9	90	6	4,500	36	62	73	12–6	40	32	22,500
10	150	10	4,500	36	62	73	12–6	40	32	22,500

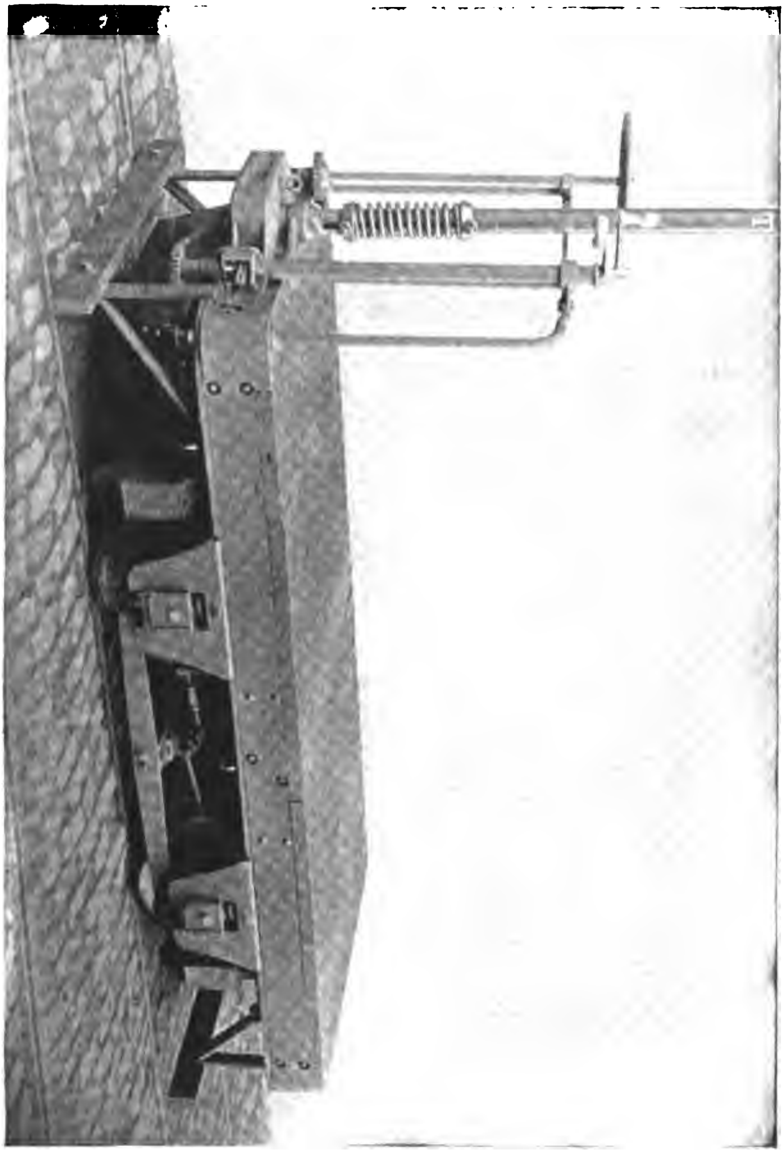


Fig. 336—General Electric Factory Truck.

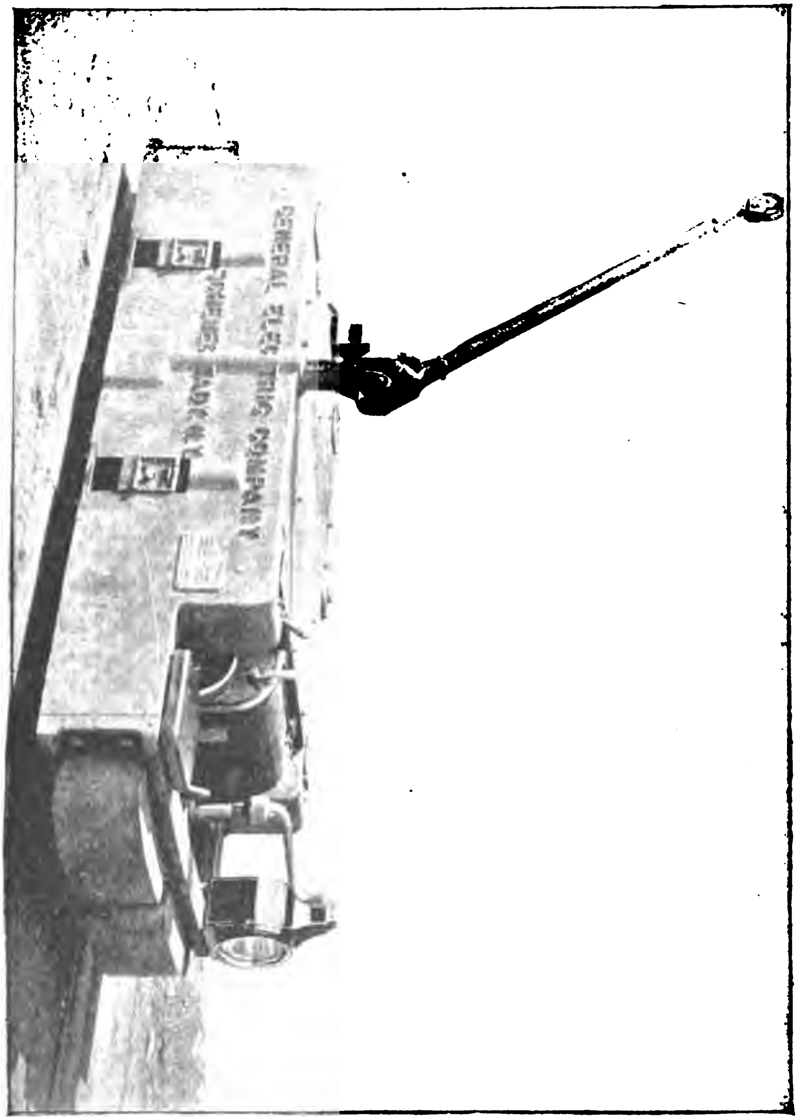


Fig. 337—General Electric T.M.M.-10 Electric Locomotive.

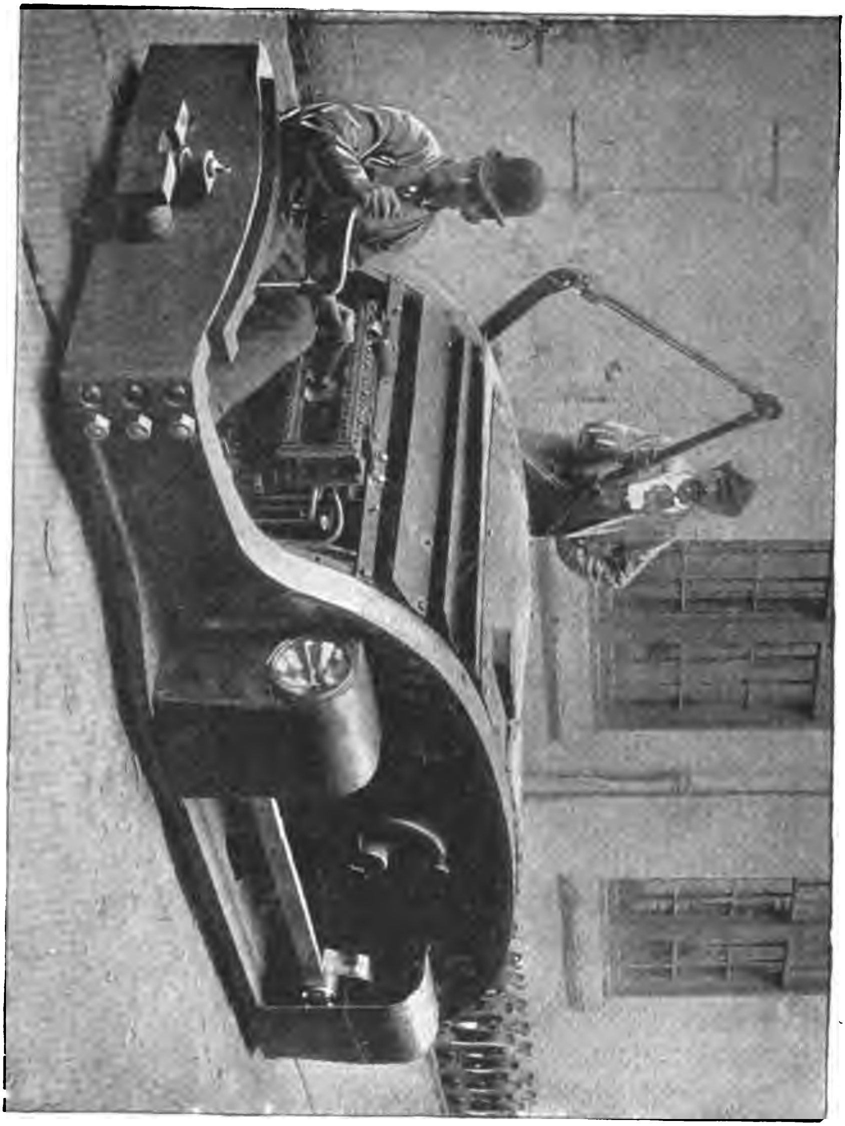


Fig. 338—General Electric "Terrapin Back" Electric Mining Locomotive.

motor, however, be disabled in any way, there are four points by which the remaining motor can be brought into single duty, and either forwards or backwards. The seventh notch is marked "emergency," and effects a short-circuit of the motors through a portion of the rheostat, after disconnecting the trolley line. The motors, if running, are in this condition caused to operate as dynamos on short-circuit, and are thus rapidly retarded and brought to rest by magnetic breaking action.

In a street-railway controller, it is necessary to provide some device for diminishing or suppressing the sparking, or arcing at the contact fingers, when a disconnection is effected. In the Walker Company's controller, this is obtained by winding a series of hollow coils or solenoids in the insulating partitions between the contact segments, one in each partition, and all parallel to the controller axis, and passing the current through all these coils in series just before breaking the circuit. This has the effect of magnetizing all the solenoids, and of causing the breaks in the circuit to take place in front of the centres of the magnetized solenoids. The arcs which tend to form are thus acted upon by the magnetic fields, and are deflected laterally away from the contacts or are blown out magnetically.

Fig. 335, shows a Walker Company's No. 25 or 200 H. P. railway motor.

A form of General Electric Company's factory-truck driven by a small electric motor, is shown in Fig. 336. This is provided with the vertical trolley pole T, a brake handle B, and a controller handle C. This truck is convenient for transporting loads in mills and factories.

One of the General Electric Company's types of mining locomotive is shown in Fig. 337. This is fitted with but one motor, and is controlled from a switch in the front platform by the side of the lamp. It takes its current from the trolley arm shown. The sizes of these mining motors is given in the accompanying table.

TABLE OF GENERAL ELECTRIC COMPANY'S MINING LOCOMOTIVES.

Rating.	Draw-Bar Pull.	Speed.	Weight	Min. Gauge.	Width over All.	Height Frame.	Length over All.	Add to Gauge to obtain Width.	Wheel Base.	Diam. Wheel.	Diam. Axle.	Height Trolley 5 ft. Pole.		Height Over Trolley	Style of Motor for Minimum Gauge.
		Miles per Hour.										Max.	Min.		
	Lbs.		Lbs.	In.	In.	In.	Ft. In.	In.	In.	In.	In.	Ft. In.	Ft. In.	In.	
TMM- 5	500	6 to 10	4400	18	34	31¾	5–10	16	22	14	2¾	7–6	3–2	35½	NWP- 2½
TMM-10	1000	6 to 10	8200	24	39½	25½	9– 0	15½	36	20	2¾	6–6	2–8	29½	LWP- 5
TMM-15	1500	6 to 10	12000	30	49	32	11– 6	19	44	28	3⅜	7–0	3–3	36	NWP- 6
TMM-25	2500	6 to 10	20000	36	55½	34	11–10	19½	44	28	3⅜	7–3	3–6	38	NWP-12

NOTE.—For best results and most economical running, the minimum weight of rail per yard for TMM-5 is 18 lbs.; for TMM-10, 25 lbs.; for TMM-15, 30 lbs.; for TMM-25, 40 lbs. These figures may be modified by local conditions. In mining work, 30 to 35 lbs. per ton* should be taken for the draw-bar pull necessary to move the load on a level. Twenty pounds per ton must be added for every per cent. of grade.

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* Short tons.

Fig. 339, shows an electric locomotive of this type drawing a train of loaded cars. Here the trolley wire is suspended overhead at a low elevation.

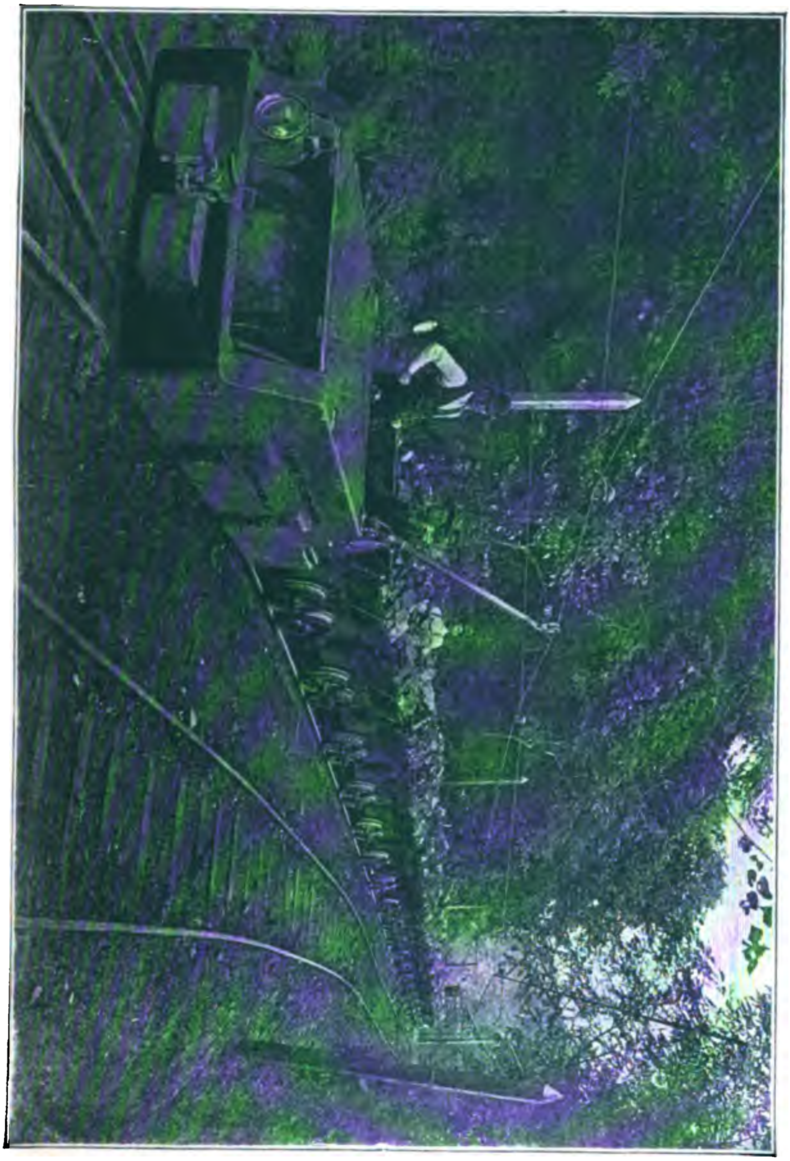


Fig. 339—General Electric T. MM.-25-Electric Locomotive with Loaded Trip.

Fig. 340, shows the General Electric Company's thirty-ton electric locomotive, coupled to a train of freight cars, and receiving its power from a trolley line. Such locomotives are sometimes employed for surface haulage. The following is a table of their dimensions :—

TABLE OF SIZES AND CAPACITIES OF GENERAL ELECTRIC COMPANY'S T. M. F. LOCOMOTIVES FOR SURFACE HAULAGE.

No.	*Draw-Bar Pull.	Speed in Miles per Hour.	Class.	Number of Motors.	Minimum Gauge.	Wheel. Base.	Diam. Wheels.	Length.	Width.		Height of Platform.	Height over Cab.		Weight.
	Lbs.				In.	Ft.	In.	Ft.	Ft.	In.	In.	Ft.	In.	Lbs.
1	250	6	2½–6	1	18	2	20	7	3 —	3	24			2,500
2	250	10	2½–10	1	18	2	20	7	3 —	3	24			2,500
3	500	6	5 –6	2	18	2	20	7	3 —	3	24			3,000
4	500	10	5 –10	2	18	2	20	7	3 —	3	24			3,000
5	400	6	4 –6	1	24	2	20	7	3 —	9	24			4,000
6	400	10	4 –10	1	24	2	20	7	3 —	9	24			4,000
7	800	6	8 –6	2	24	3	20	7	3 —	9	24			5,000
8	800	10	8 –10	2	24	3	20	7	3 —	9	24			5,000
17	700	6	7 –6	1	30	5	30	12½	6 —	5	42	11 —	10	8,000
18	700	10	7 –10	1	30	5	30	12½	6 —	5	42	11 —	10	8,000
19	1,500	6	15 –6	2	30	5	30	12½	6 —	5	42	11 —	10	10,000
20	1,500	10	15 –10	2	30	5	30	12½	6 —	5	42	11 —	10	10,000
21	1,200	6	12 –6	1	36	5	30	12½	6 —	5	42	11 —	10	13,000
22	1,200	10	12 –10	1	36	5	30	12½	6 —	5	42	11 —	10	13,000
23	2,500	6	25 –6	2	36	5	30	12½	6 —	5	42	11 —	10	16,000
24	2,500	10	25 –10	2	36	5	30	12½	6 —	5	42	11 —	10	16,000
25	2,000	7½	20 –7½	1	56½	5	36	12½	6 —	5	42	11 —	10	18,000
26	2,000	10	20 –10	1	56½	5	36	12½	6 —	5	42	11 —	10	18,000
27	4,000	7½	40 –7½	2	56½	5	36	12½	6 —	5	42	11 —	10	24,000
28	4,000	10	40 –10	2	56½	5	36	12½	6 —	5	42	11 —	10	24,000

* For approximate load in tons, hauled, on a level, divide the draw-bar pull by 15.

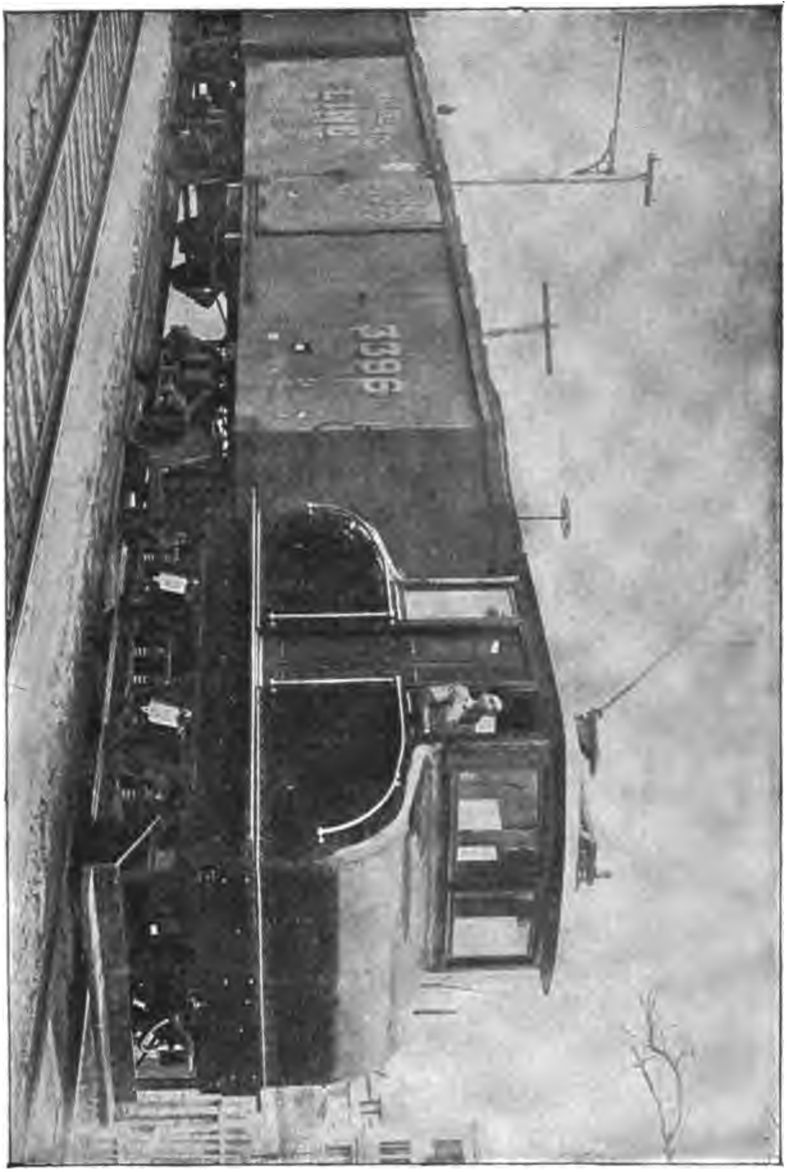


Fig. 340—General Electric 30-Ton Electric Locomotive.

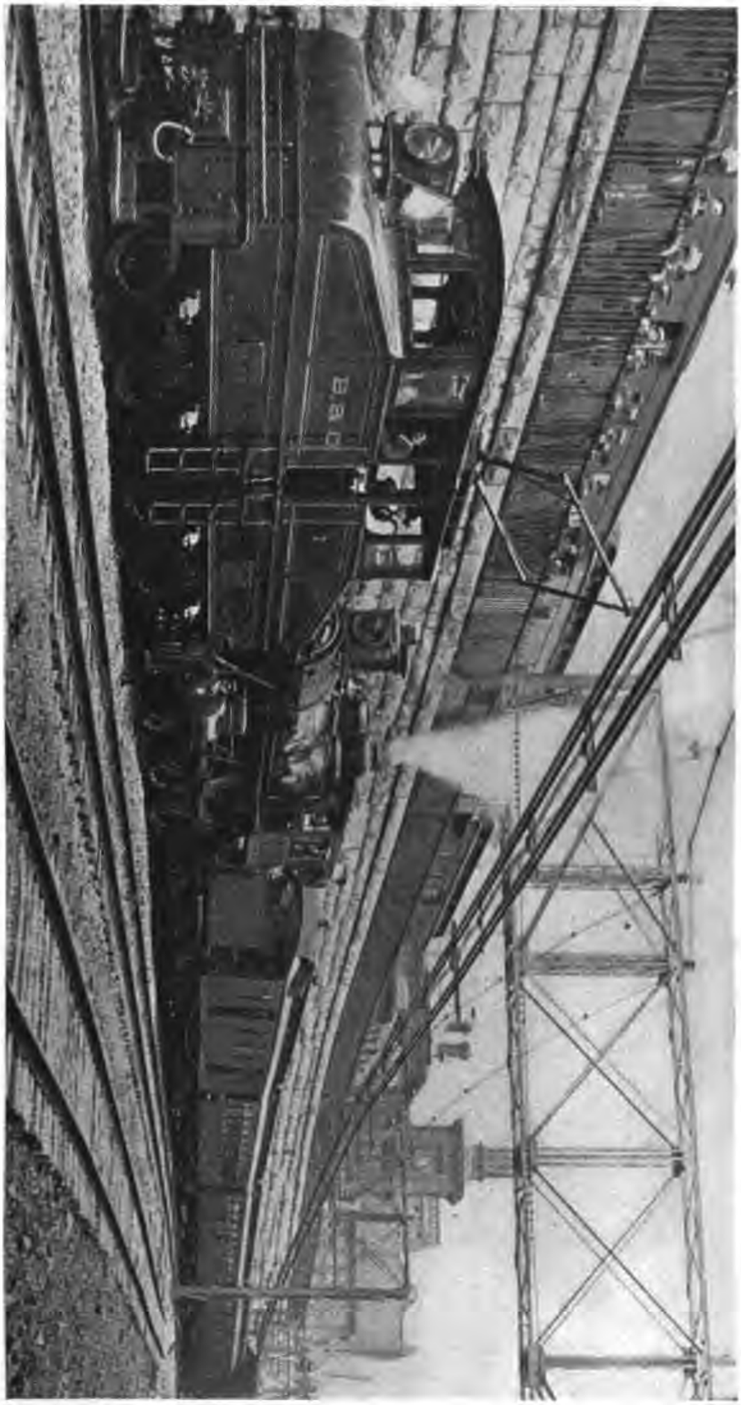


Fig. 341—"General Electric" Locomotive No. 1, B. & O. R. R.

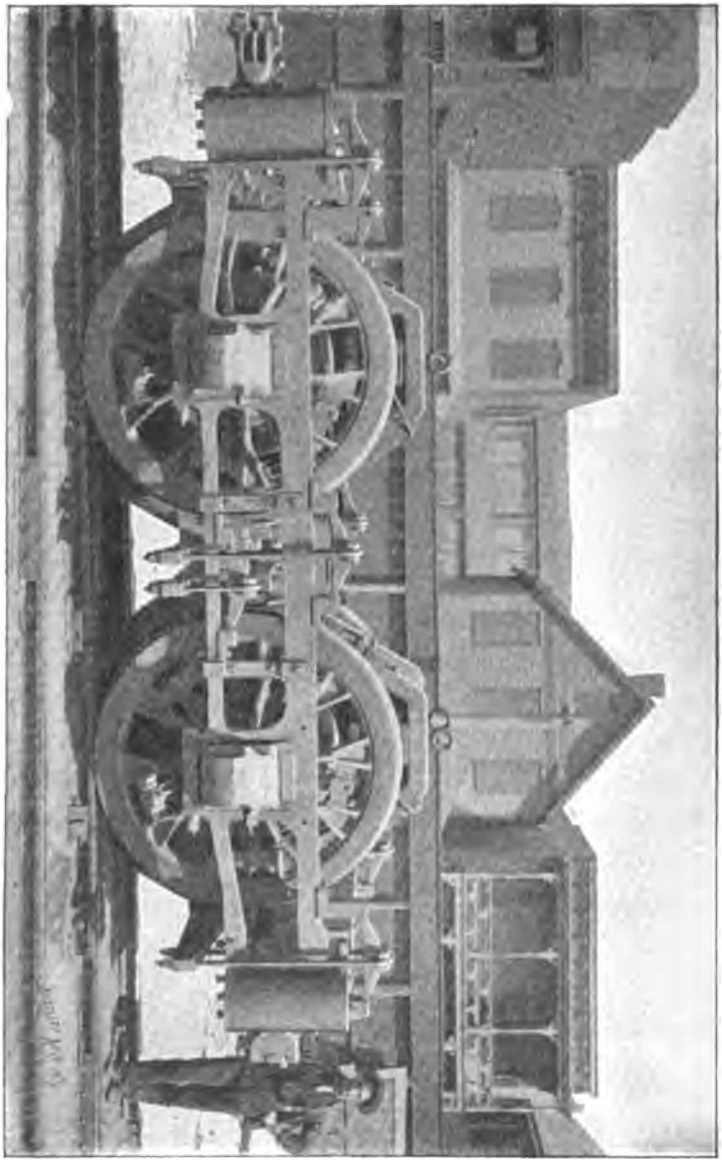


Fig. 342—Truck for General Electric B. & O. Electric Locomotive.

Fig. 341, shows a General Electric Company's large locomotive of 1,500 H. P., hauling a passenger train with its engine through the Baltimore tunnel, on the Baltimore and Ohio Railroad. This use of the electric locomotive is for the purpose of avoiding the accumulation of smoke in the tunnel, which is of considerable length. In place of the usual trolley wheel, power is taken from the overhead conductor, by means of a heavy contact shoe sliding in the conductor trough shown.

This electric locomotive weighs 190,000 lbs. It is provided with two motor trucks, one of which is shown in Fig. 342. Four six-pole motors are, therefore, placed on the locomotive, each wound for 250 volts. Its maximum speed is 70 miles an hour, and its draw-bar pull at 15 miles per hour is 42,000 lbs.; the starting draw-bar pull being as high as 60,000 lbs. The locomotive is 34 feet 6 inches long, 14 feet 3 inches high, and 9 feet 6¼ inches wide. The drivers, of which there are 8, are 62 inches in diameter, and all exert power equally.

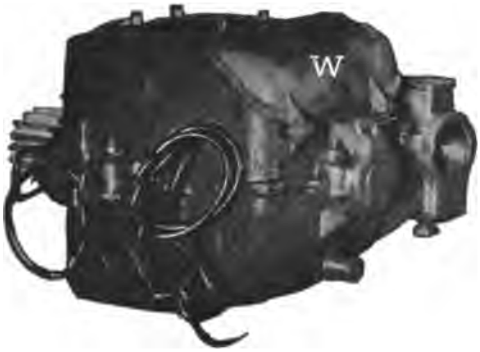


Fig. 343—A General Electric G. E. 800 Motor.

Fig. 343, shows a General Electric Company's G. E. 800 motor, i.e., a motor capable of delivering to a car a horizontal effort of 800 lbs., on a level, under normal conditions. The frame is practically water-tight, is made of cast steel, and in two portions. The upper portion has a flap or window W, by which access can readily be had to the brushes for inspection.

Fig. 344, shows a General Electric Company's G. E. 1,000 motor closed, and Fig. 345, the same motor, opened. The motors shown in Figs. 343 to 345, are of the quadripolar type, with two field coils; i. e., two salient poles, and two conse-

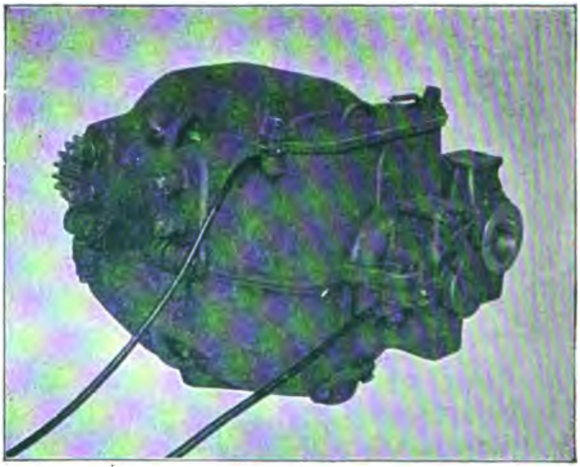


Fig. 344—General Electric G. E. 1000 Motor.—Closed.

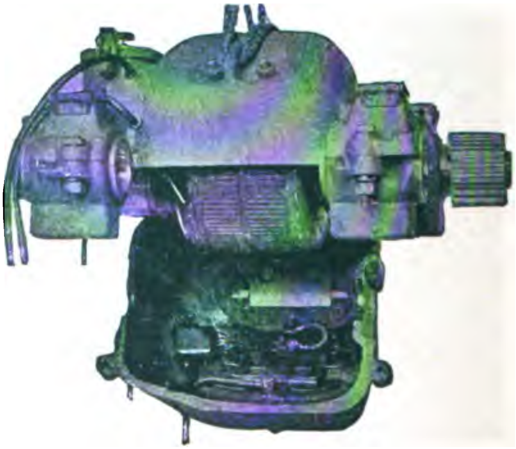


Fig. 345—General Electric G. E. 1000 Motor.—Open.

quent poles. Fig 346, shows an armature of one of these motors in course of winding.

The field coils are thoroughly insulated with asbestos, mica, and paper. A covering of heavy duck encloses the winding and is drawn together and sewed after the spool has been wound, thus enclosing the coils.

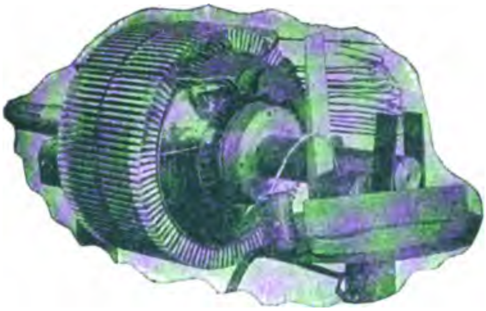


Fig. 346—Armature in Course of Construction.

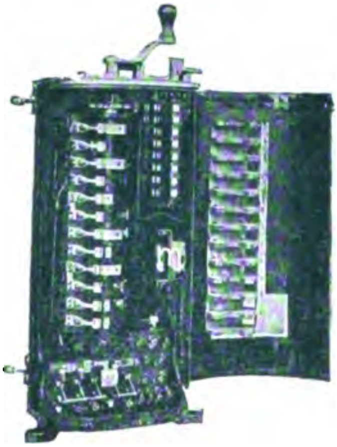


Fig. 347—"General Electric" Series-Parallel Controller. Form K.

Fig. 347, shows the interior of a General Electric Company's series-parallel controller. In this controller of form K. there are two cylinders. One in the centre for effecting the various contacts, by which the two motors of the car are placed in series or in parallel, to control their speed and pull; and a smaller one on the right for reversing the armatures and the direction of the car's motion when necessary. The wires are connected to the small terminal board at the base, while the switches in the left-hand corner are for throwing out of circuit one or other of the motors, should either happen to be defective. The arcing at breaking contacts is suppressed by a magnetic blow-out; a large magnet being inserted in the circuit so that the contacts are broken beneath its poles.

Fig. 348, shows two General Electric Company's motors,

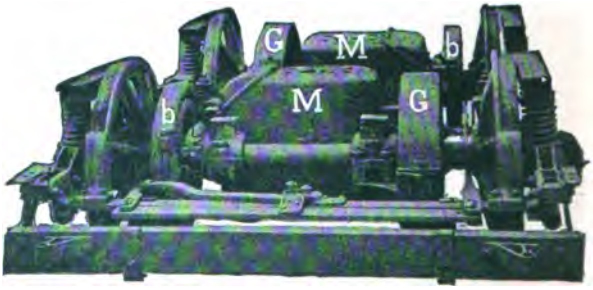


Fig. 348—General Electric Motor Truck, with Electric Brakes.

M, M, supported in a street-car truck, and provided with electric brakes, b b. G, G, are the gear covers. The electric breaks are electromagnets of a special form, which are excited by the current supplied from the motor armatures after the trolley connection has been shut off at the controller; i. e., by the current taken from these armatures running as dynamos. The brake is shown in Fig. 349. It is a circular magnet held securely on the motor frame, while its armature is a plate revolving with the car wheel.

A Westinghouse Electric Company's No. 12 A, street-railway motor, closed and ready for mounting is seen in Fig. 350. The two portions of the frame are hinged together as shown. The two bearings visible are the armature shaft bearing and the car axle bearing respectively. The insulated conductors leading to the field and armature are shown upon the upper portion, and pass through its surface.

Fig. 351, shows the same motor with its lower frame thrown open. This opening can only be done when the motor is mounted in a truck, by bringing the truck over a pit in a car-shed. The releasing of the lower frame in this manner enables the interior of the motor to be inspected without re-

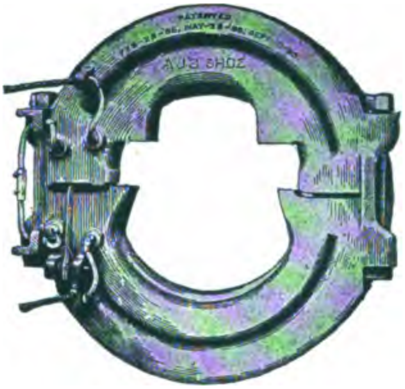


Fig. 349—" General Electric " Electric Brake.

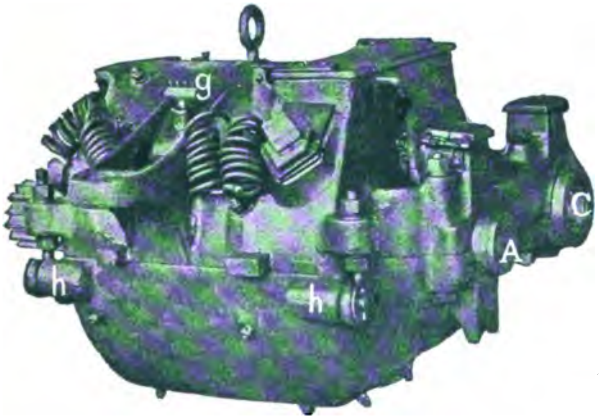


Fig. 350—Westinghouse No. 12-A Motor Ready for Mounting on Axle.

moving it from the truck. N and S, are a pair of field-magnet poles in the lower frame.

Fig. 352, shows the same motor mounted with parallel side-bar suspension. b, b, b',.b', are the parallel side-bars, while B, B, is the cross-bar which is supported in its turn from the side frames of the truck. .These motors are usually constructed in 25 H. P. and 30 H. P. sizes. Two motors are placed on each car truck. A 30 H. P. motor is usually geared in the ratio of 68 : 14 with the car wheel and with 30" wheels delivers 1,100 lbs. horizontal pull to a car when running on a level at full load.

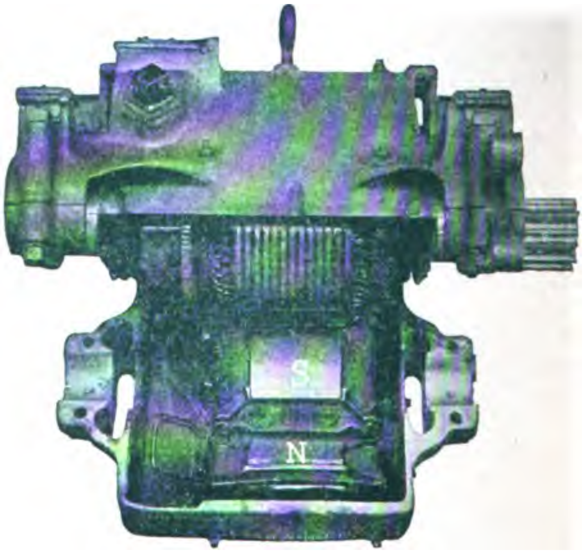


Fig. 351—Westinghouse No. 12-A Motor with Lower Field Opened Down.

Fig. 353, represents the core of a Westinghouse No. 12 A, 30 horse-power standard speed motor, with two formed wound coils placed in grooves upon its surface. Figs. 354, 355, and 356, show the appearance of the armature in various stages of winding, while Fig. 357, represents the appearance of the armature when completed. This armature has 47 slots or grooves on its surface and 93 commutator bars. The manner in which the winding is effected is represented diagrammatically in Fig. 358, where the first coil is placed in

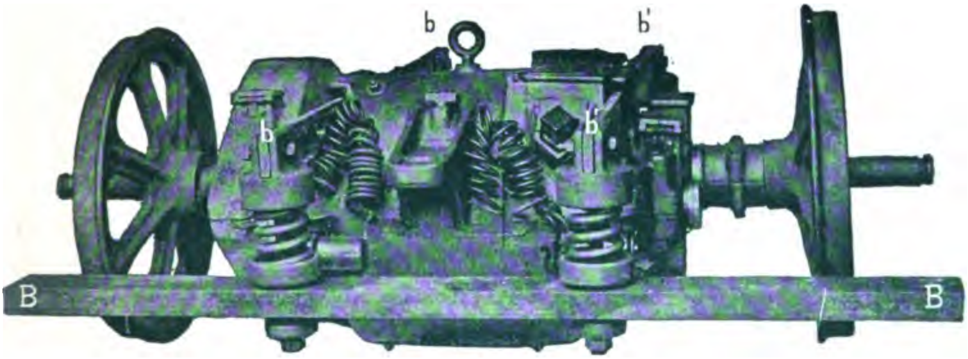


Fig. 352—Westinghouse No. 12-A Motor, Mounted—Showing Parallel Side Bar Suspension.

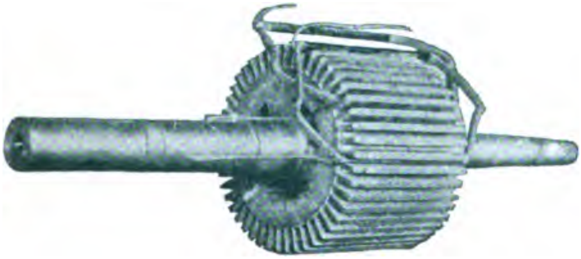


Fig. 353—Core of Westinghouse 30-H.P. Street Car Motor.

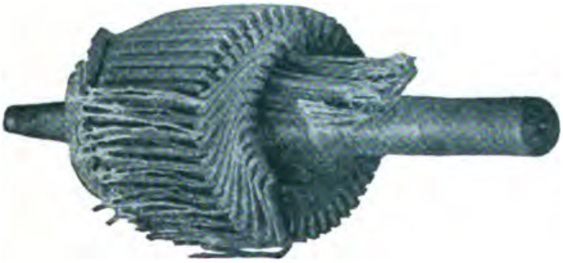


Fig. 354—Westinghouse Motor Armature in Process of Winding.

slots Nos. 1 and 11, slot No. 1 being so selected because it is immediately opposite to a commutator bar. The coils are

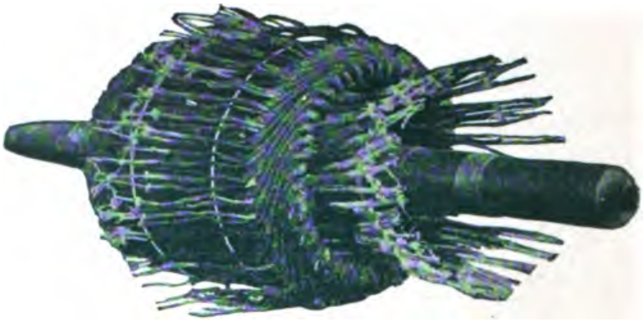


Fig. 355—Westinghouse Motor Armature in Process of Winding.

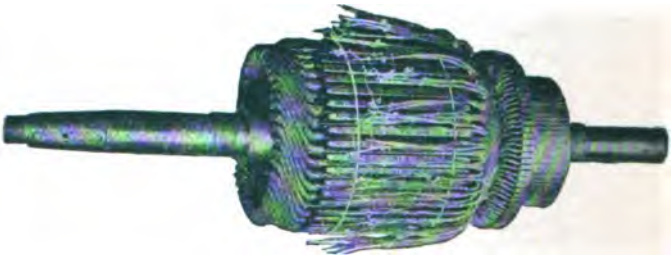


Fig. 356—Westinghouse Motor Armature in Process of Winding.

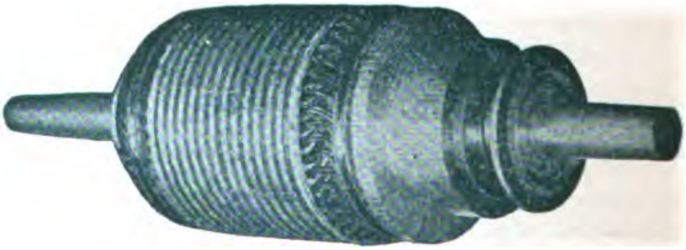


Fig. 357—Completed Armature for Westinghouse No. 12-A Motor.

formed on a machine in the exact shape that they will retain after being placed upon the core. Each coil has two windings, a white and a black winding. It, therefore, has four ends; two white and two black. The first coil as shown in Fig. 358, has its black ends cut off short, so that the black winding is left unutilized. This is necessary in order to accommodate the winding, and accounts for the fact that there are 93 commutator bars, or one less than twice the number of slots. The coils are laid on successively in a clockwise direction all round the armature, the left-hand side being uppermost, and the right-hand side lowermost in the slots. The ends on the right-hand side of each coil are carried to the right-hand for connection to the commutator. Similarly, the ends on the left-hand side are carried to the left. The positions at which these ends are soldered to the commutator segments are nearly opposite to each other and are shown in Fig. 358.

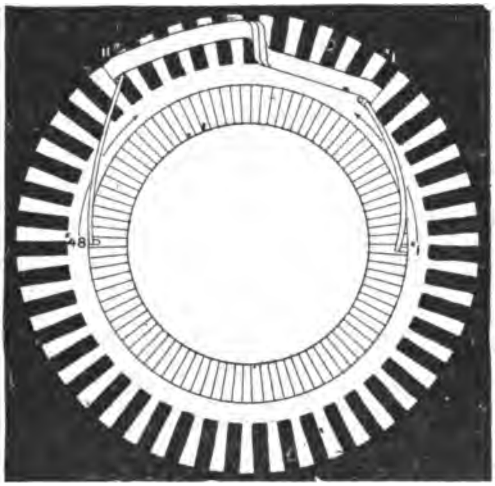


Fig. 358—Diagram of Westinghouse 30-H.P. Armature Core.

The connections of the completed armature are illustrated in Fig. 358. For the sake of simplicity, however, this figure only shows 21 slots in the armature, instead of 47, and 82 ends connected to 41 commutator bars. The teeth on the surface are indicated by black rectangles. Of the four wires lying between adjacent teeth; say, Nos. 1, 2, 3 and 4, the right-hand pair are the lowermost in the slot, and the left-hand pair the uppermost. Black wires are represented by black lines, and white wires by dotted lines. The radial portions of the figure represent the wires on the surface of the armature, while the arcs of circles which connect the radial portions with the commutator and with each other, represent the portions of the winding at the ends of the armature. The black wire No. 2, in slots 1 and 5, is suppressed, i. e., disconnected. With the brushes fixed in the position shown, and with the armature occupying the position represented in the

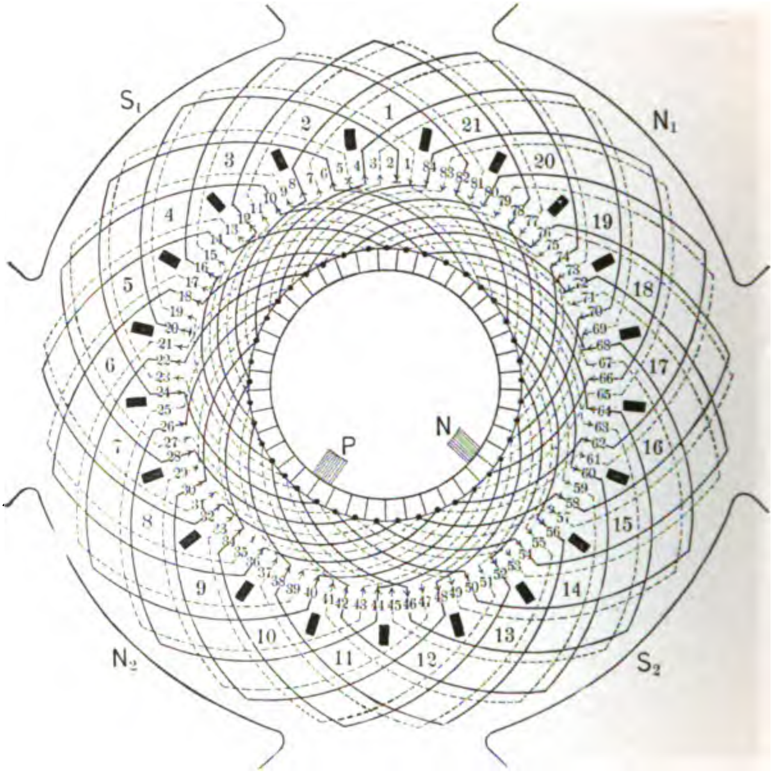


Fig. 359—Connections of Westinghouse Completed Armature.

figure, the current enters the armature on the positive brush P, and takes two courses through the windings; namely, first, one clockwise via wires, *23*, *5*, *63*, *45*, *19*, *1*, 60, 42, 16, 82, *59*, *41*, *15*, *81*, 56, 38, 12, 78, *55*, *37*, *11*, *77*, 52, 34, 8, 74, *51*, *33*, *7*, *73*, 48, 30, 4, 70, *47*, *29*, *3*, *69* to the negative brush N. Secondly, counter-clockwise by the wires *49*, *67*, *9*, *27*, 50, 68, 10, 28, *53*, *71*, *13*, *31*, 54, 72, 14, 32, *57*, *75*, *17*, *35*, 58, 76, 18, 36, *61*, *79*, *21*, *39*, 62, 80, 22, 40, *65*, *83*, *25*, *43*, to the negative brush N. The figures in Roman type are black wires, and the figures in italics are white wires. It will be seen that owing to the suppression of the wires 2, 20, there is a slight dissymmetry between the two circuits into which the current divides, but owing to the large number of wires, this dissymmetry is negligible in practice. The armature is a double-wound, two-circuit armature, without cross-connections

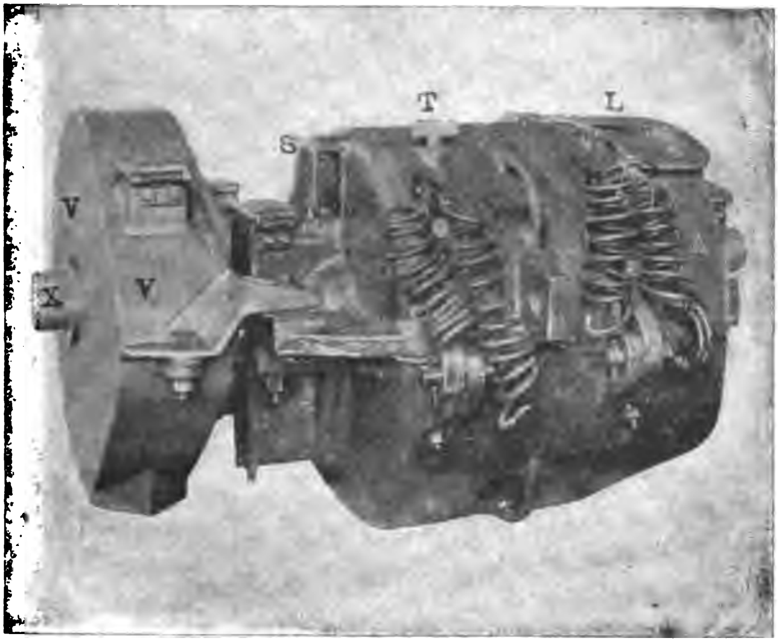


Fig. 360—Westinghouse 35-H.P. Railway Motor.

at the commutator. It is double-wound, because there is a black and a white wire in each slot, and it is a two-circuit armature because there are two paths into which the current divides between the positive and negative brushes.

A Westinghouse 35 H. P. railway motor is shown in Fig. 360, S, is a loop cast into the frame for the support of the motor on parallel side bars. The gears are enclosed in the cover V V, through which projects the armature shaft X, T, is the ground connection firmly screwed into the frame and L, is a lid for giving access to the brushes from above.

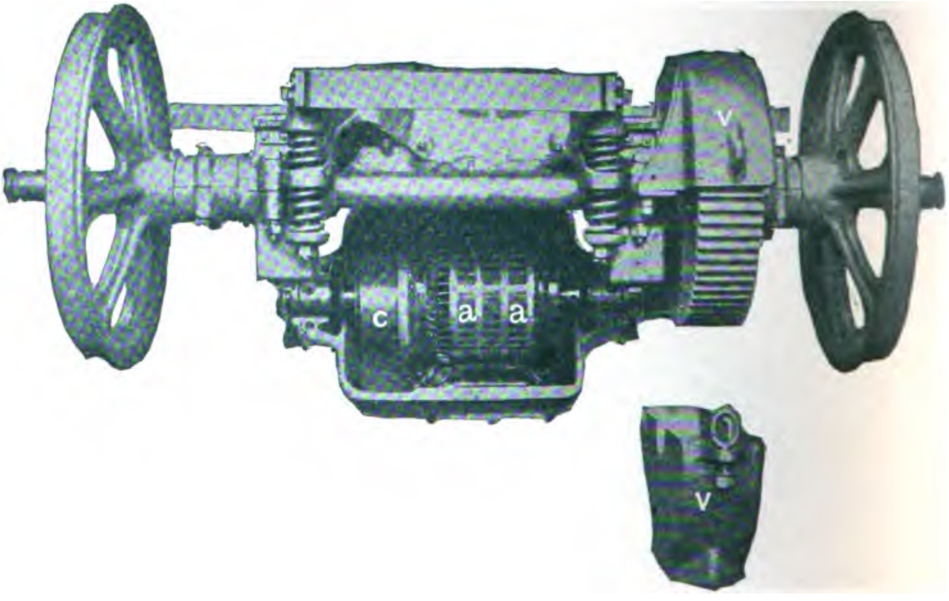


Fig. 361—Westinghouse 50-H.P. Railway Motor.

Fig. 361, shows a 50-H. P. Westinghouse railway motor with the lower case opened down and the armature a, a, also lowered, showing the commutator c, and the gear wheel. It will be seen that dust and mud are prevented from reaching the commutator by a shield or disk placed on the shaft outside the commutator.

In Fig. 362, the same 50 H. P. motor is shown with the armature raised into its position in the upper frame, and leaving the poles n and s visible in the lower frame.

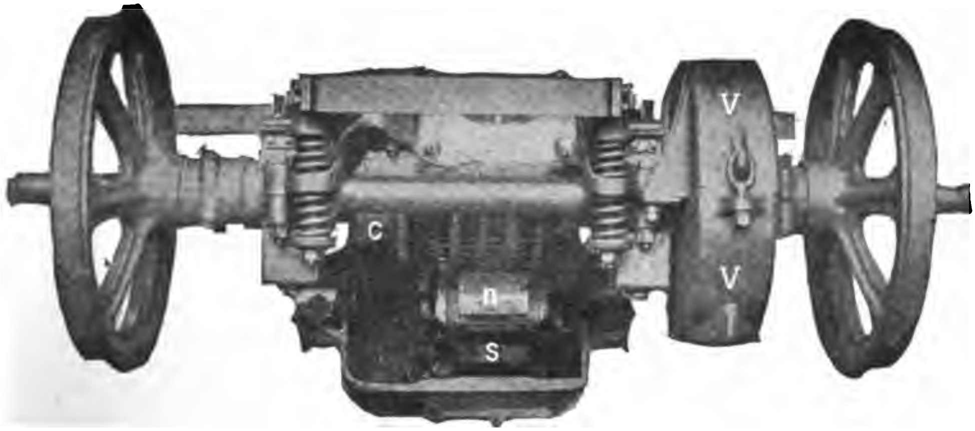


Fig. 362—Westinghouse 50-H.P. Railway Motor.

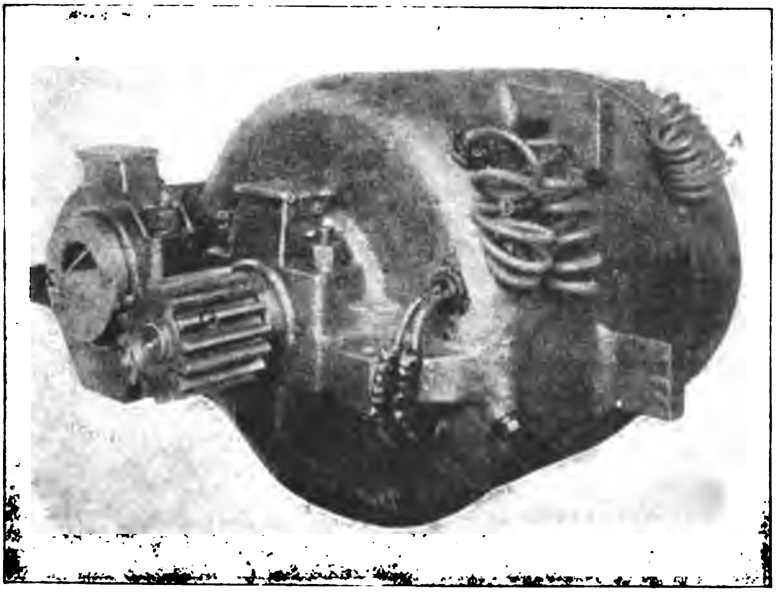


Fig. 363—Westinghouse 100-H.P. Railway Motor.

Fig. 363, shows a Westinghouse 100-H. P. Railway motor intended for cradle suspension.

The same motor is shown in Fig. 364, with the upper field removed. In this motor a joint has to be made at J, between the upper and lower field wires.

Street-car motor armatures are designed to have as little weight as possible for their power, and also as little fly-wheel

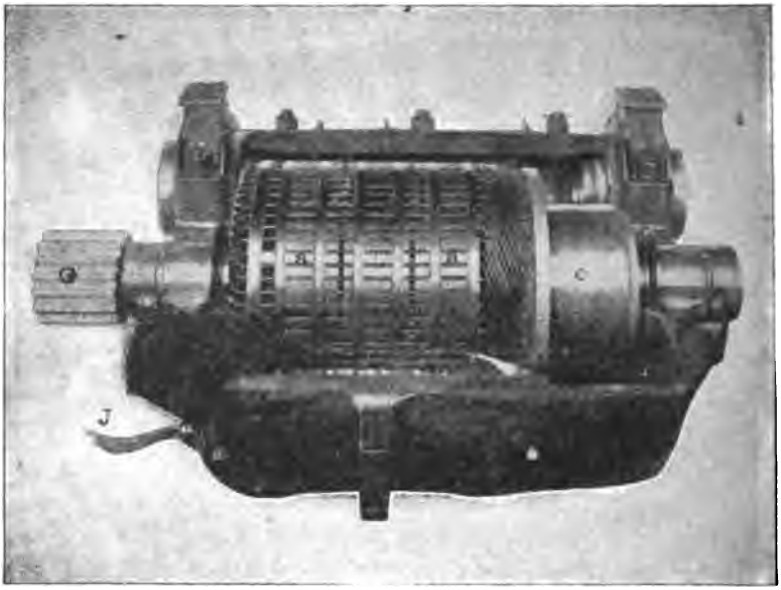


Fig. 364—Westinghouse 100 H.P. Railway Motor, Upper Field Removed.

action or rotary momentum as possible, to avoid useless inertia in starting or stopping a car. The field frames are generally constructed of soft cast steel, and only sufficient metal is allowed in the frame to give ample mechanical strength and passage to the necessary magnetic flux.

CHAPTER XII.

ALTERNATING-CURRENT MOTORS.

ALTERNATING-CURRENT motors may be divided into three classes:

1st. Those which employ a commutator and are *series-wound.*

2d. *Synchronous motors;* or, those which keep step with the alternating current which supplies them.

3d. *Asynchronous motors;* or, those which do not keep step with the alternating current supplying them.

These classes may be sub-divided into *uniphase* or *single phase motors*, and *multiphase* or *polyphase motors.* The second class of synchronous motors, in their ordinary form, when constructed of the single-phase type, are not self-starting, but are self-starting under light load when of the multiphase type. The third class of asynchronous motors are commonly employed under the title of *induction motors.*

Before the general introduction of the multiphase motor, and at a time when all the alternating-current circuits were single-phase, various means had to be resorted to in order to operate the few single-phase motors of any size which were installed at that time. One of these means was to employ the exciters as generators and motors over the line, working by continuous currents, and with the aid of the exciter to bring the armature of the single-phase machine up to or beyond the requisite speed for synchronism. As soon as this was attained the exciters were withdrawn to their regular duty, and the single-phase motor connected with the alternating-current circuit, at the proper moment so as to fall into step. Another method was to employ a small multiphase motor of the "*split-phase*" type, that is to say a multiphase motor in which the multiphase currents were locally produced from a single-phase circuit, to bring the larger armature of the single-phase machine up to speed. This difficulty of starting uniphase synchronous motors, rendered them very objectionable except in cases where the motor had to run for a long period without stopping.

Although single-phase alternating-current motors are not self-starting in large sizes, yet, in small sizes, a number of different alternating-current motors are constructed. The smallest of these is, perhaps, found in the Westinghouse Company's Shallenberger meter, which is illustrated in Fig. 365. Here, the cover is removed from the instrument and the interior parts are clearly visible. C C, is the coil carrying the alternating current, whose strength is to be measured and integrated; c, is a smaller coil, of bare copper conductor, placed inside the coil C C, and at an angle with it. Within the interior coil c, is a small disc armature, shown at D, in Fig. 366. This armature is formed of corrugated metal, with an iron external ring on the edge. When the alternating current passes through the coil C C, it induces an alternating

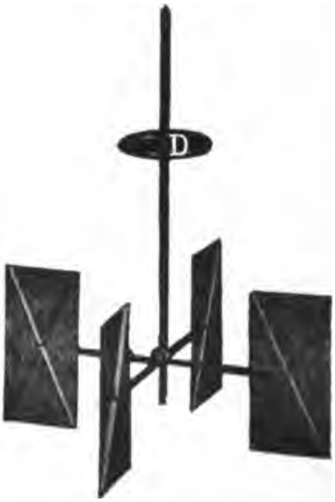


Fig. 366—Revolving Parts of Westinghouse Shallenberger Meter.

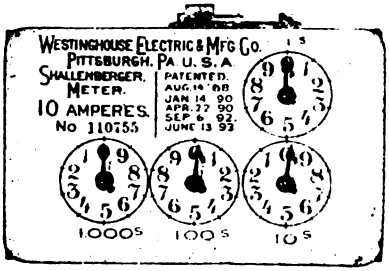


Fig. 367—The Dial.

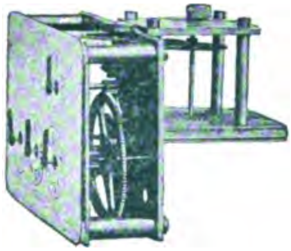


Fig. 368—Recording Gears.

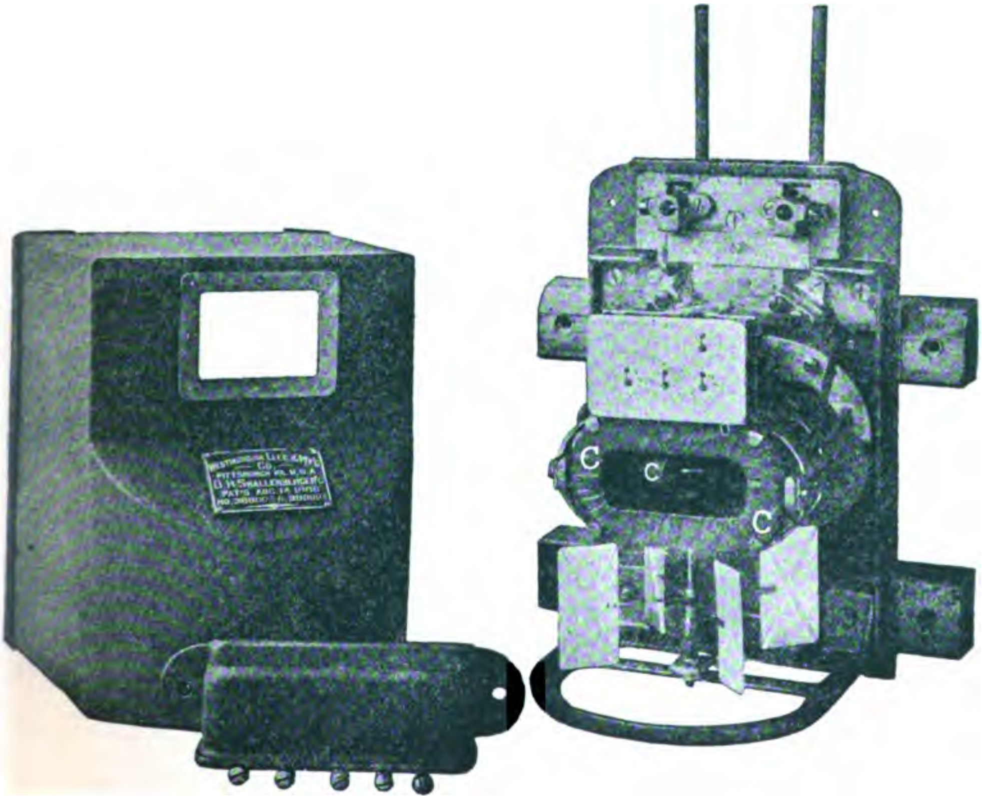


Fig. 365—Westinghouse Shallenberger Meter with Cover Removed.

current in the closed copper coil c. The current in the interior coil is out of step with the current in the outer coil, and their joint magnetic influence produces an elliptically rotating magnetic-field around the disc armature. The disc armature tends to rotate in unison with the rotating magnetic-field, and its rotation is opposed by the resistance of the air to the rotating fan blades. The speed of the disc armature and fan blades is proportional to the current strength passing through the instrument. The dial and recording gear are shown in Figs. 367 and 368.

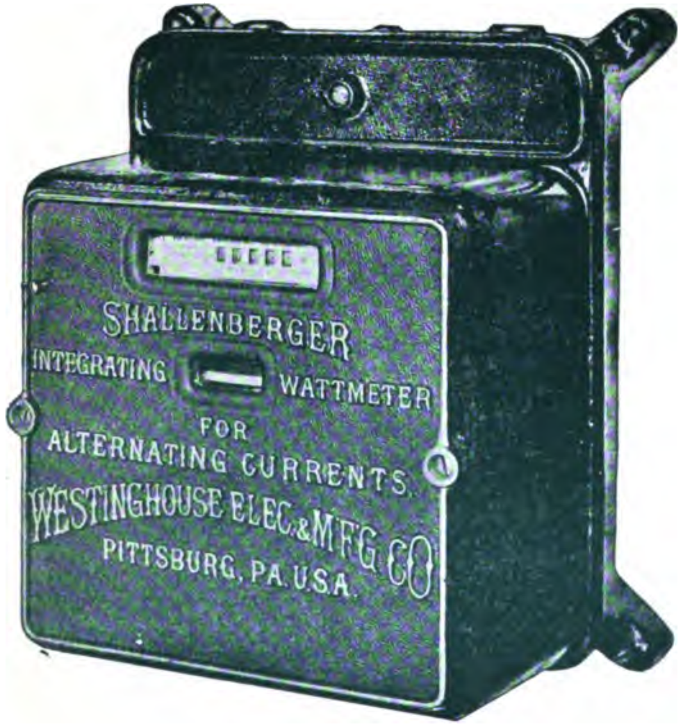


Fig. 339—Westinghouse Integrating Wattmeter.

Fig. 369, shows a Westinghonse Electric Company's Shallenberger integrating wattmeter, for alternating-current circuits. The instrument is shown with its cover removed in Fig. 370. Here a horizontal disc pivoted on a vertical axis,

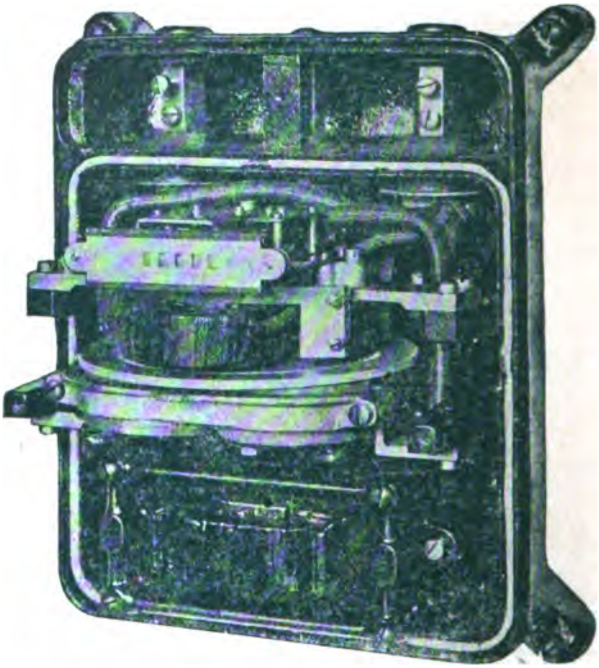


Fig. 370—Westinghouse Integrating Wattmeter with Cover Removed.

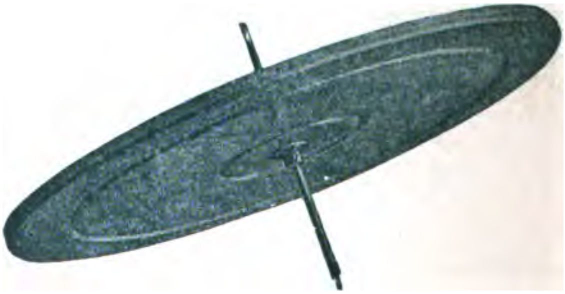


Fig. 371—Disc-Armature of Westinghouse Integrating Wattmeter.

and shown separately in Fig. 371, is free to rotate under the poles of one alternating-current magnet, and above the poles of another alternating-current magnet. The currents in these two magnets are out of phase, and their reactive magnetic effects upon eddy-currents established in the metallic disc, produce in it a speed of rotation proportional to the rate in watts at which energy is being delivered through

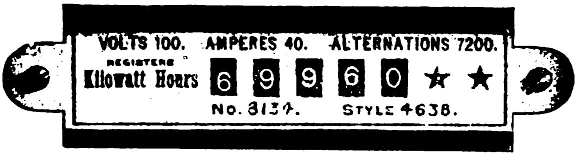

VOLTS 100. AMPERES 40. ALTERNATIONS 7200.
REGISTERS
Kilowatt Hours
6 9 9 6 0 ★ ★
No. 3134.
STYLE 4638.

Fig. 372—Dial of Westinghouse Integrating Wattmeter.

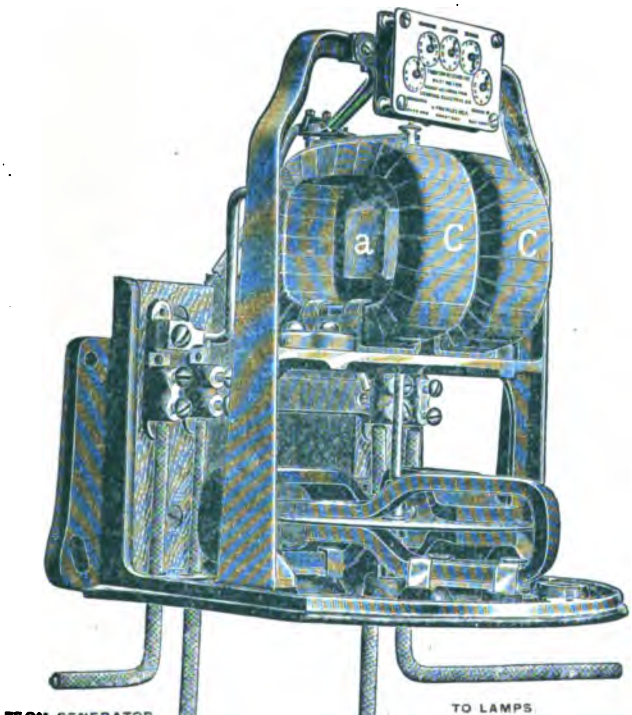


Fig. 373—General Electric Two-Wire Thomson Wattmeter.

the apparatus. The dial of the instrument is shown in Fig. 372.

Another small uniphase motor is found in the General Electric Company's Thomson recording watt-meter, which is equally applicable to alternating and continuous currents. This instrument is shown in Fig. 373. It consists of a small motor without iron, provided with a commutator and brushes, a hollow armature at a, and a pair of field coils C, C. The field coils carry the current whose strength is to be measured and integrated, while the armature a, receives through its brushes resting on the commutator, a feeble current supplied between the mains through a suitable high resistance placed in the instrument. The manner in which the machine operates on a continuous-current circuit, will be sufficiently evident from this description. When connected, however, to an alternating-current circuit, the magnetism in the armature reverses at each alternation of the pressure in the mains, while the magnetism in the field coils reverses at every alternation of the current supplied through the instrument. Consequently, at each alternation the magnetic pull reverses both in the armature and in the field, thereby maintaining a constant direction of motion in the armature. The motion of the armature is opposed by an *electro-magnetic brake*, composed of a horizontal copper disc, at the lower part of the instrument, mounted on the armature shaft and revolving through the air gaps of three permanent magnets. The passage of the copper disc through the polar gaps of these magnets sets up eddy currents in the copper which are magnetically acted upon and which tend to check the speed of rotation. The speed of the armature under these conditions is proportional to the power supplied through the machine in watts.

Small fan motors are also constructed to be operated by a uniphase alternating current. In a few instances these have to be started from rest by hand, but those which we are about to describe start automatically.

Fig. 374, shows a Lundell alternating-current fan motor, suitable for circuits of 60 cycles or upwards. The switch at the base is for starting the motor and for inserting a choking coil for varying the speed. Three speeds can be obtained of 1,200, 1,400 and 1,600 revolutions per minute respectively.

The General Electric Company's single-phase alternating-current fan motors are shown in Figs. 375 and 376. The method of operating one of these motors is shown in Fig.

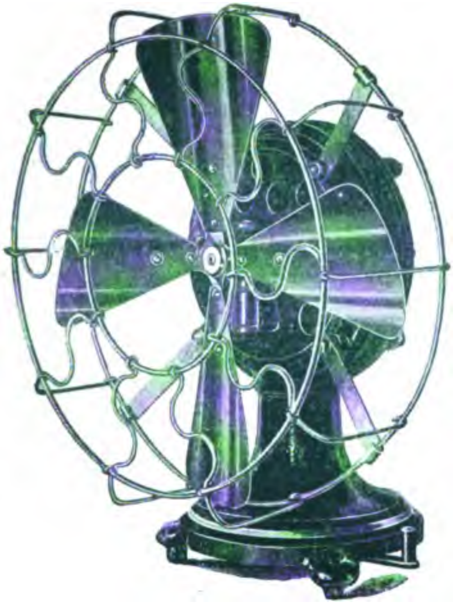
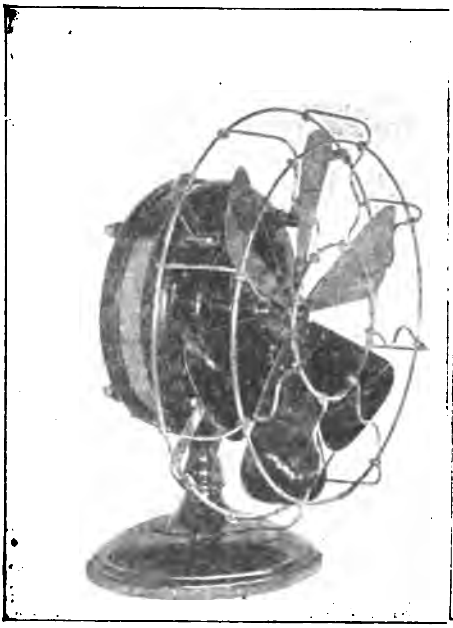


Fig. 374—Lundell Alternating-Current Fan Motor.

377. The armature consists of a laminated core, with slots containing bare copper conductors forming a simple squirrel-cage or short-circuited winding. The field is laminated, and the field coils are held in place upon the inwardly projecting pole-pieces. These projections are divided at their extremities into two branches. On one of these branches, a *shading coil*, formed of a copper ring is placed, while the other branch is left unshaded. The magnetic field produced under the

shaded half of the pole-pieces, is out of step with the magnetic field produced in the unshaded half, and the resultant effect is a tangential pull upon the armature setting up rotation. The speed of rotation is about 1,800 revolutions per minute. Eight poles are employed, on high-frequency circuits of, approximately, 130 cycles, and four poles, on low-frequency circuits of, approximately, 60 cycles.



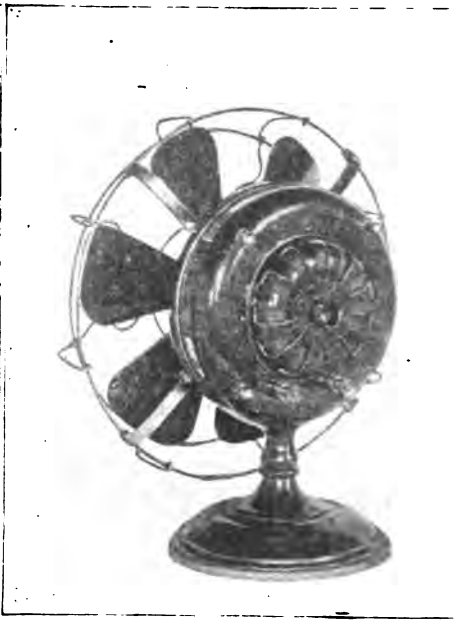


Fig. 375. Front View, **Fig. 376. Rear View,** of "General Electric" Company's Single-Phase Alternating Current Fan Motor.

Fig. 378, shows a Westinghouse Electric Company's alternating-current fan motor. Here, the armature is also a laminated mass with bare copper conductors forming a squirrel-cage. The switch, at the base, starts and controls the speed of the motor within certain limits.

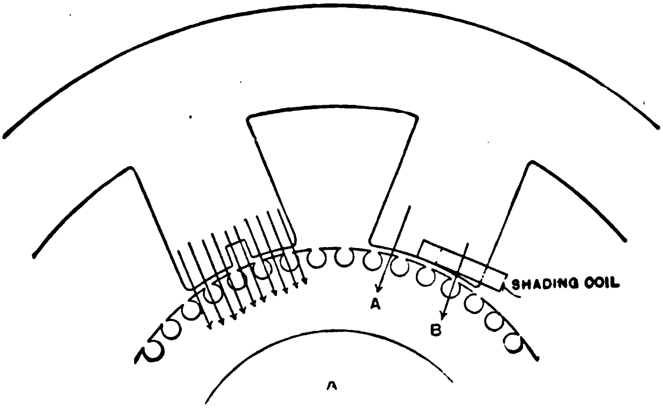


Fig. 377—Diagram of General Electric Alternating Current Fan Motor.

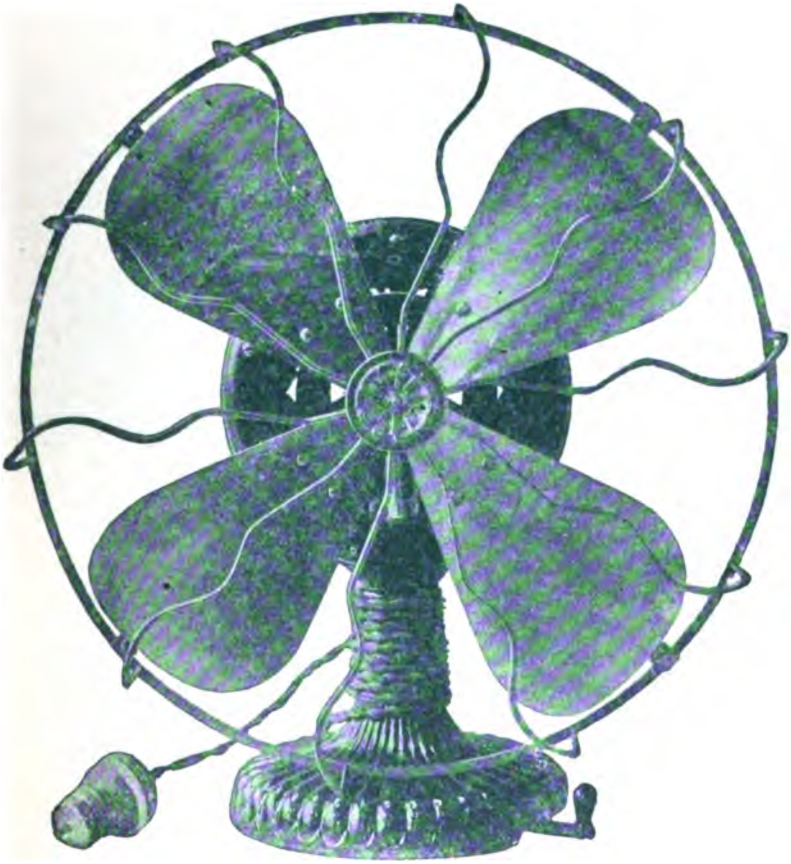


Fig. 378—Westinghouse Alternating Current Fan Motor.

Fig. 379, shows a Fort Wayne Electric Corporation's 7½ H. P. uniphase alternating-current motor. This motor consists essentially of a synchronous single-phase alternating-current motor with an additional winding, whereby it is enabled to start and come up to synchronous speed as a series-wound uniphase motor. That is to say, the field is connected in series with the armature, to start it from rest and bring it to speed, and after the motor has attained full speed, the series field is cut out of circuit, while the winding on the armature connected with the commutator, supplies continuous currents to excite the field magnets continuously. The motor is, therefore, supplied with a pair of collector rings, on one side of the armature, and with a commutator and brushes, on the other side, as shown in Fig. 380. The connections of this motor are shown in Fig. 381. The main

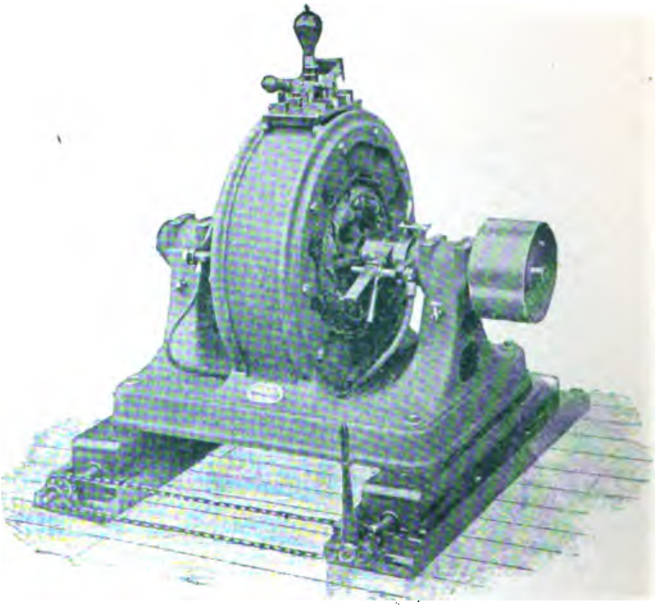


Fig. 379—Fort Wayne Uniphase Alternating Current, 7-½ H.P. Motor.

uniphase circuit is connected by branches with the double-pole primary fuse box, and the primary winding of the transformer. The secondary winding of the transformer is brought to the main switch of the motor through a double-pole fuse block. When the main switch is closed, the secondary circuit of the transformer is connected to the motor switch S. This motor switch has three positions. In the forward position, as shown in the figure, it starts the motor; in the back position it runs the motor after starting; and, in the intermediate position, it cuts the motor out of

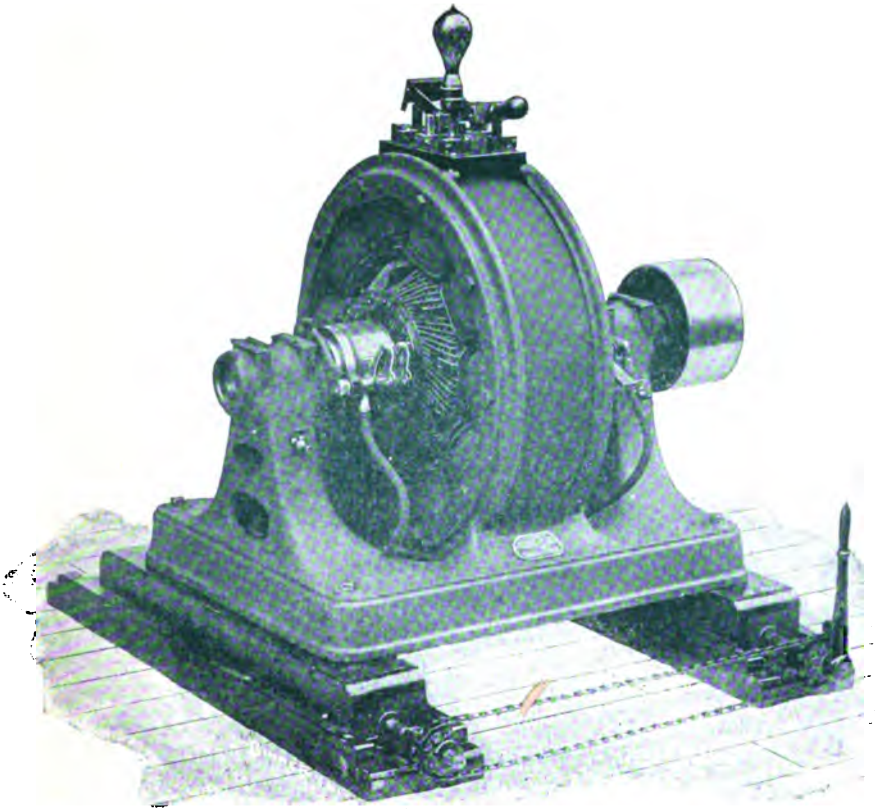


Fig. 380—Commutator Side of Fort Wayne Uniphase Alternating Current Motor.

circuit and stops it. As shown in the figure, alternating currents are admitted to the motor, through the brushes resting on the commutator, and through the series field coils f. This causes the magnetism in the armature winding to reverse at each cycle, at the same time that the magnetism in the series field coils is reversed, so that a steady magnetic effort is exerted upon the armature in one direction, despite the reversals of current. After the motor has been brought up to full speed, the *pilot lamp* connected to the alternating-current side of the armature lights up. The switch is then thrown to the back position, thereby closing the alternating-current circuit through the armature collector rings, while the brushes on the commutator are closed through the shunt field *S*, and the rheostat R. The armature is, therefore,

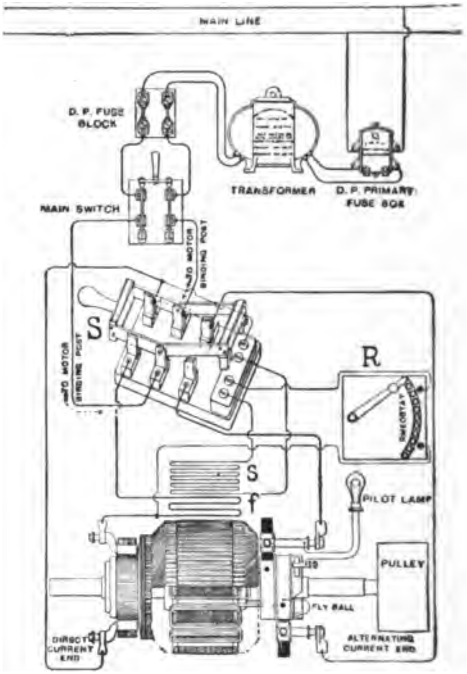


Fig. 381—Connections for Standard Fort Wayne Motor.

working as a motor, on the alternating-current side, and by the aid of the commutator is working as a generator on the continuous-current side, supplying continuous currents to the field magnet shunt-winding, while the field magnet series-winding is out of circuit. The machine operates in this condition as an ordinary synchronous single-phase motor. The motor is by this device enabled to start with a considerable torque. The sizes of this machine are shown in the accompanying table.

Although it is thus possible to operate single-phase motors and start them from rest, yet it practically requires in this case the union of a continuous-current motor with an alternating-current motor in order to effect the starting and running. The multiphase alternating-current motor has, therefore, been introduced in order to supply a self-starting motor for alternating-current circuits.

Multiphase motors may be divided into two classes; namely, *synchronous motors*, and *non-synchronous* or *asynchronous motors*. Synchronous multiphase motors keep step with the alternations of the current supplied and, therefore, run at a fixed rate independent of the load. As usually constructed they have a comparatively feeble starting torque and develop a stronger torque when they reach synchronous speed.

Asynchronous multiphase motors do not keep step with the alternations of the current supplied to them, and, consequently, do not run at a fixed speed. Their speed is below that of synchronism, but they tend to reach synchronism at no load. As their load is increased, they fall slightly in speed or develop what is called a *slip*, so that at full load they run at from one and a half to seven per cent below synchronous speed according to the size and design of the motor. These motors have a powerful starting torque, and are suitable for all the purposes which call for frequent starting and stoppings.

Fig. 382, shows three General Electric Company's *triphase synchronous motors* located at a sub-station in Sacramento, DIMENSIONS OF FORT WAYNE SELF-STARTING SINGLE-PHASE ALTERNATING-CURRENT MOTORS.

140 to 60 Complete Periods per Second.

HORSE-POWER.	REVOLUTIONS PER MINUTE				NUMBER OF POLES	SIZE PULLEY				WIDTH OF BELT (Single)	SPACE REQUIRED, INCLUDING SLIDING BASE			WEIGHT	
	140 Periods	133 Periods	125 Periods	60 Periods		Diameter	Face	Bore	Size Key		Length (Direction of Shaft)	Width	Height	Armature	Motor Complete
1	2800	2670	2500	1200	6	4	1¾	⅝	. . . .	1½	20	27	26	30	175
2½	2800	2670	2500	1200	6	4	2½	13/16	⅛ x ⅛	2	25	30	32	50	300
5	2100	2000	1875	900	8	6	3½	1	3/16 x 3/16	3	32	33	34	100	540
7½	1680	1600	1500	720	10	8	4½	1¼	¼ x ¼	4	38	39	38	180	890
10	1400	1330	1250	600	12	10	5½	1⅝	5/16 x 5/16	5	49	48	44	300	1300

California. The motors are at the right-hand side, and drive arc-light and incandescent-light generators on the left-hand side. Each motor is of 333 H. P., has sixteen poles, and makes 450 revolutions per minute. They receive triphase currents at a pressure of 550 volts. Each machine is practically a *triphase generator* operated inversely as a motor.

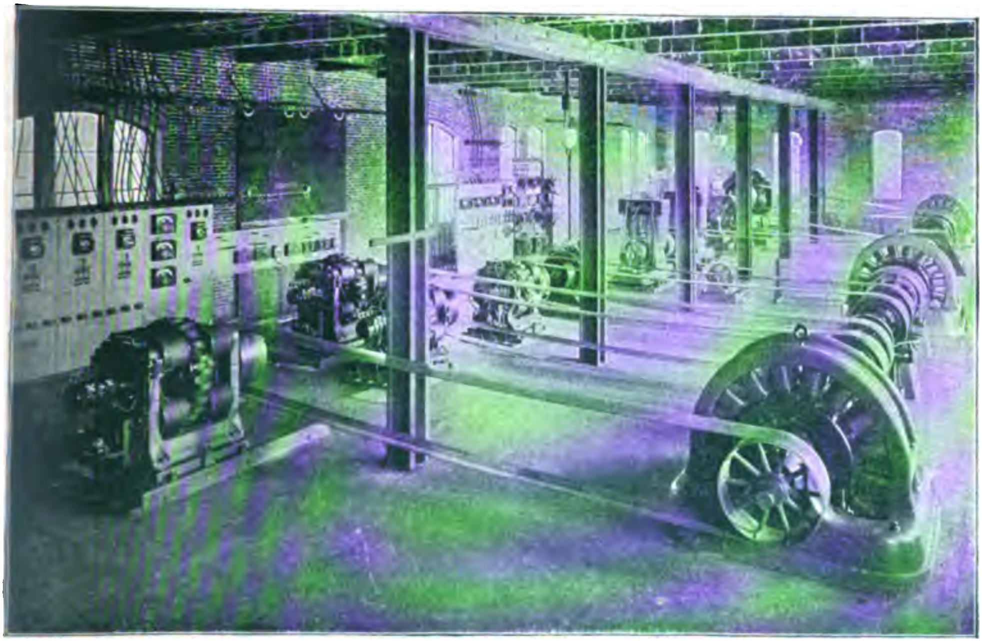


Fig. 382—Three General Electric Triphase Synchronous Motors.

Fig. 383, shows a type of Westinghouse Electric Company's *asynchronous* or *polyphase induction motor.* This machine has either four terminals, two for each of the two circuits constituting the *diphase system*, or three terminals, when wound for the triphase system. The stator field of this motor is show in Fig. 384. It consists of a laminated field structure, provided with slots for the reception of coils. The coils are connected with each of the two circuits in such a manner that a ***rotating magnetic field*** is produced in one direction or the other around the frame. Consequently, a piece of iron would have to rotate around the interior of the frame at a fixed rate in order to keep opposite to one of the poles when the field circuits are closed. The rotor armature of the motor is shown in Fig. 385. It consists of a laminated hollow

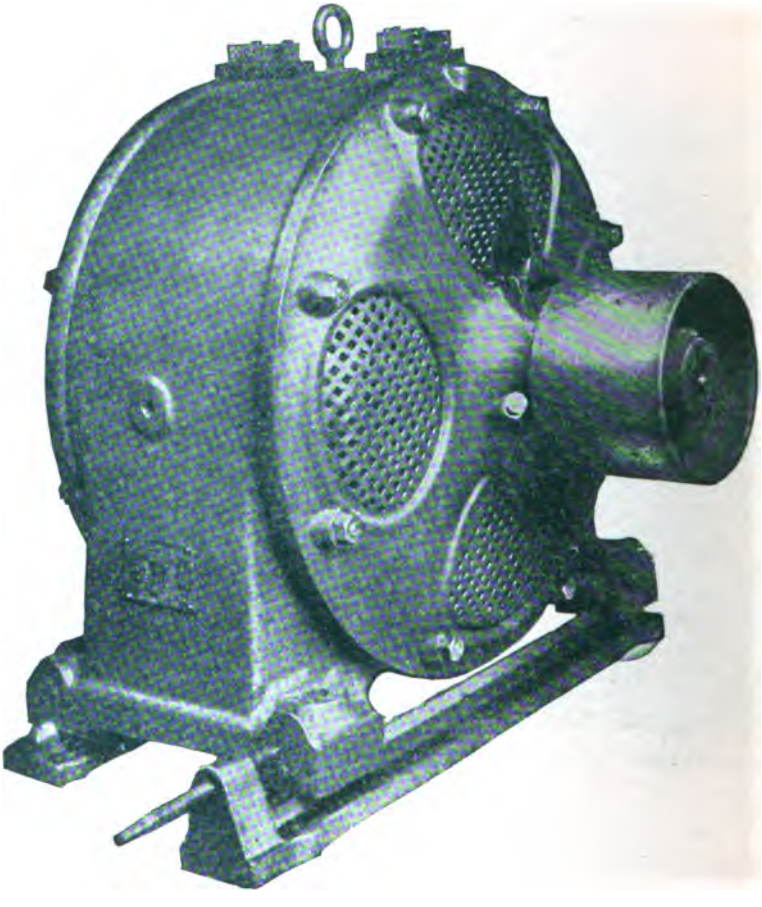


Fig. 383—Westinghonse Polyphase Type "C" Motor.

core, with slots through which pass a number of copper bars. These bars are rigidly clamped at each end of a pair of copper rings, so that the armature winding is virtually a squirrel cage, or assemblage of short-circuited bars. It is, therefore, practically impossible to burn out an armature which consists of sheet iron, bar copper and insulating material.

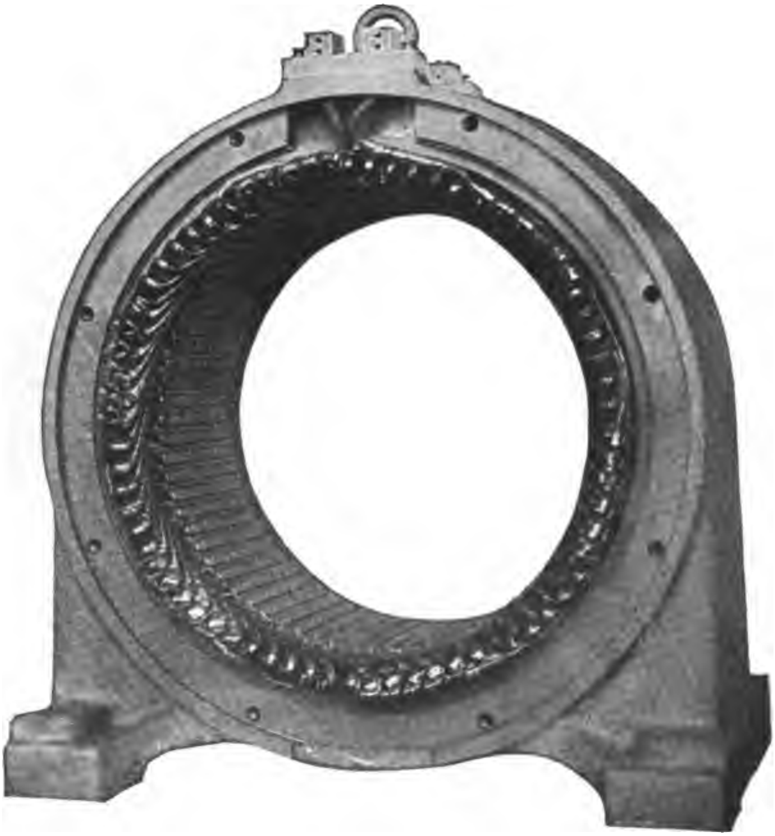


Fig. 384—Westinghouse Polyphase Type "C" Motor. Primary.

The rotation of the magnetic field around the periphery of the armature sets up very powerful currents in the short-circuited winding. The magnetic pull of these currents on the rotating field, establishes a correspondingly powerful torque. If the speed of the armature were made equal to that of the rotating field there would be no relative cutting of magnetic flux, by the short-circuited conductors, and consequently, there would be no induced currents or torque. The motor therefore, depends for its torque upon the *differential speed*, or slip, of the armature behind the speed of rotation of the magnetic field established by the multiphase currents. The greater this slip up to a certain limit, the greater the pull which the armature will exert in trying to keep up with the field. This type of motor has no contact brushes, or collector rings or short-circuiting devices, and merely requires attention to the supply of oil to its armature bearings, which are self-oiling.

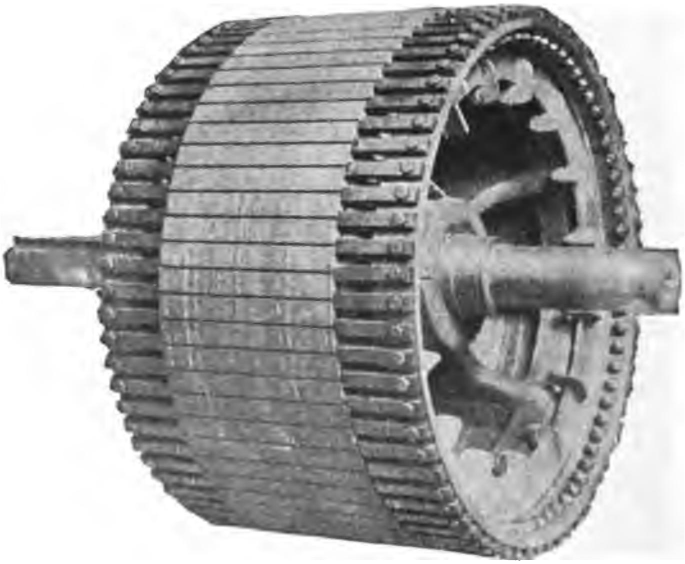


Fig. 385—Armature of Westinghouse Polyphase Motors.

When such an induction motor is started from rest the difference in speed between its rotary field and its armature is necessarily very great, and at this time the current absorbed is greater than at any other time. The starting torque of one of these motors at normal voltage is several times the full-load torque, so that both the current absorbed by the motor and the torque are reduced at the starting by reducing the pressure of the terminals. Fig. 382, shows the connections employed for this purpose. PP, P′P′, are the primary coils of two diphase transformers, PP, being connected to one primary circuit, and P′P′, connected to the other primary circuit. SS, S′S′, are the corresponding secondary circuits of the two transformers, the pressure and current generated in SS, being in diphase relationship, or 90° out of phase with respect to the pressure and current generated in S′S′. If the primary pressure, is, say 2,000 volts, and the secondary pressure 100 volts, then there will be 100 volts between the wires 1 and 3, and also 100 volts between the wires 2 and 4. These wires are connected to the two motor circuits when the motor is running

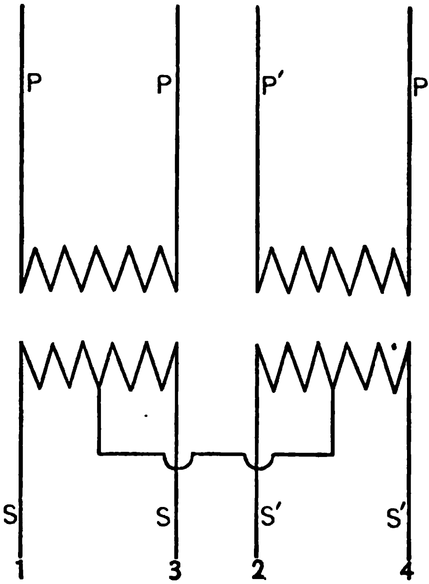


Fig. 386—Diagram of Starting Connections Westinghouse Diphase Motors.

at speed. By inter-connecting the centres of the two secondary coils, the pressure between 1 and 2, is, approximately, 70 volts, and this is also the pressure between 2 and 3. These pressures are, moreover, in diphase relationship. Consequently, in starting, the motor is connected across 1 and 2, and 2 and 3, receiving thereby 70 volts on each circuit, instead of 100 volts on each circuit.

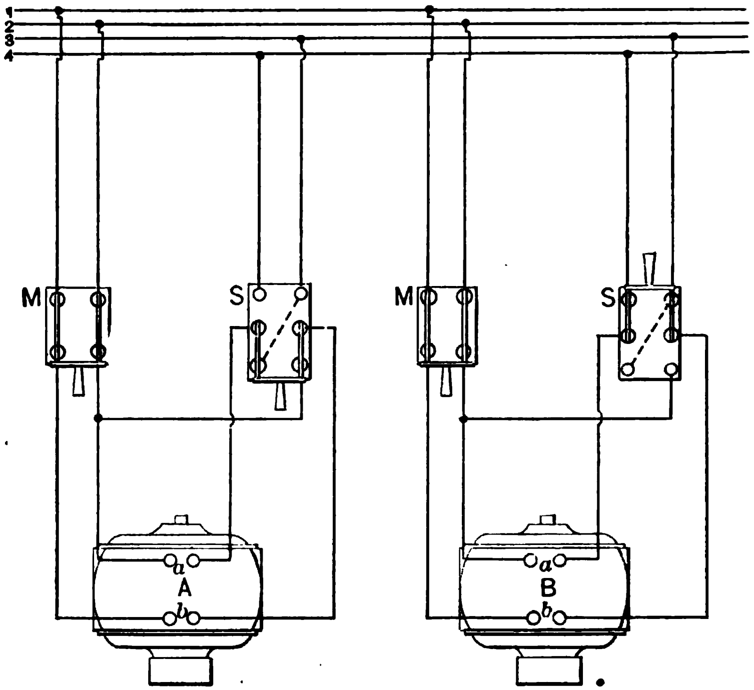


Fig. 387—Westinghouse Diphase Motor Starting Connections.

Fig. 387, illustrates these connections. M, is a main switch, and S, a throw-over switch, employed in starting. Two motors are shown; one A, on the left-hand side, in the position of starting, and one B, on the right-hand side, in the position of running. The switch S, of A, is thrown down. This connects one pair of motor circuits between wires 1 and 2, while the other pair of motor circuits is connected across 2 and 3. This brings 70 volts upon each of the motor circuits. At B, the starting switch S, has been thrown up. This brings one motor circuit (b) between wires 1 and 3, and the other motor circuit (a) between wires 2 and 4. The motor is now operated at 100 volts pressure.

When it is desired, not only to start and stop an induction motor, but also to reverse its direction of rotation, an additional switch is employed. This is represented in Fig. 384. Here the main switch is a single pole switch at M. S, is the throw-over starting switch, and R, is a throw-over reversing switch. The function of the throw-over reversing switch is merely to reverse the connection between one pair of mains; namely, 2 and 4, with the motor. This is for the reason that if we reverse the pair of wires entering the "*a*" terminals, or if we reverse the pair of wires entering the "*b*" terminals, we reverse the direction of rotation of the armature, but if we reverse both pairs, we leave the direction of rotation unchanged.

Another method of starting, employed by the Westinghouse Company, by what is called an *auto-starter*, is illustrated in Fig. 389. C and C′, are two *auto-transformers*, resembling transformers in appearance, but having a single winding for both primary and secondary. These are tapped at certain points by switches s, s′. At the highest points, the full pressure, and at the lowest point the lowest pressure, is brought to act on the motor. The main switch M, has four blades and three positions. When thrown up for running, it connects the motor terminals directly to the circuits A and B. When thrown down as shown, for starting, it connects the coils C and C′, across the circuits A and B, respectively and introduces a certain portion of the pressure across these coils upon the motor circuits a and b, the amount of this pressure depending upon the position of the switches *s*, *s*′. The intermediate position of the main switch interrupts the circuits. In order to start the motor the switch is thrown down, thereby bringing a reduced diphase pressure to the motor. After the motor has started, the switch is thrown up, thereby cut-

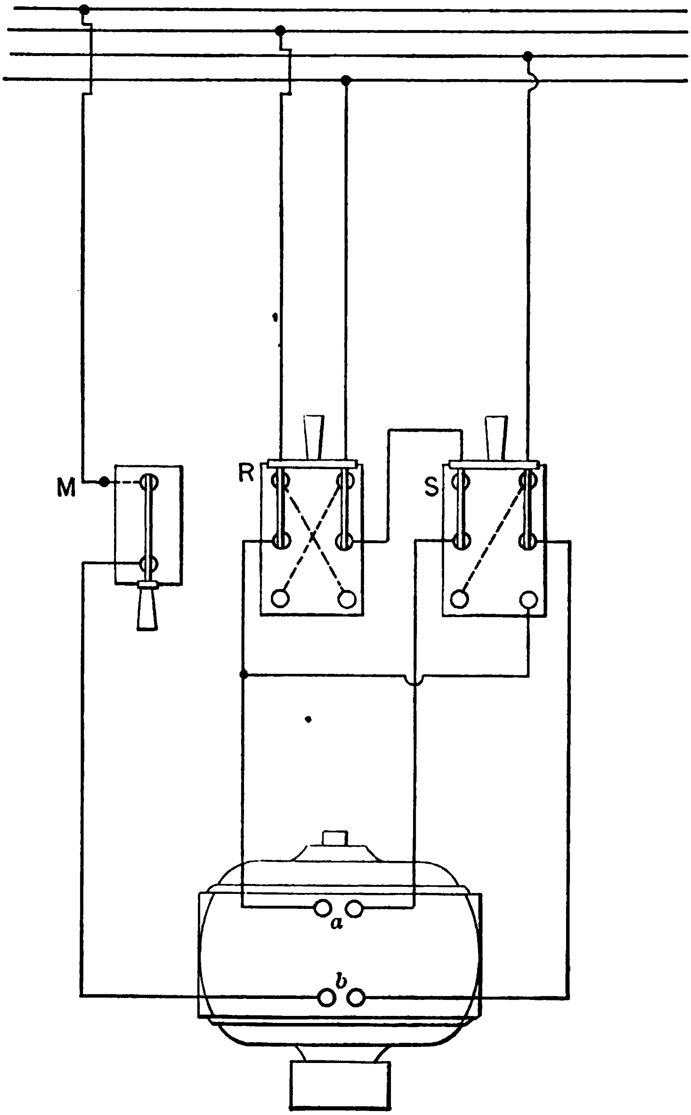


Fig. 388—Starting and Reversing Connections of a "Westinghouse" Type C Two-phase Induction Motor.

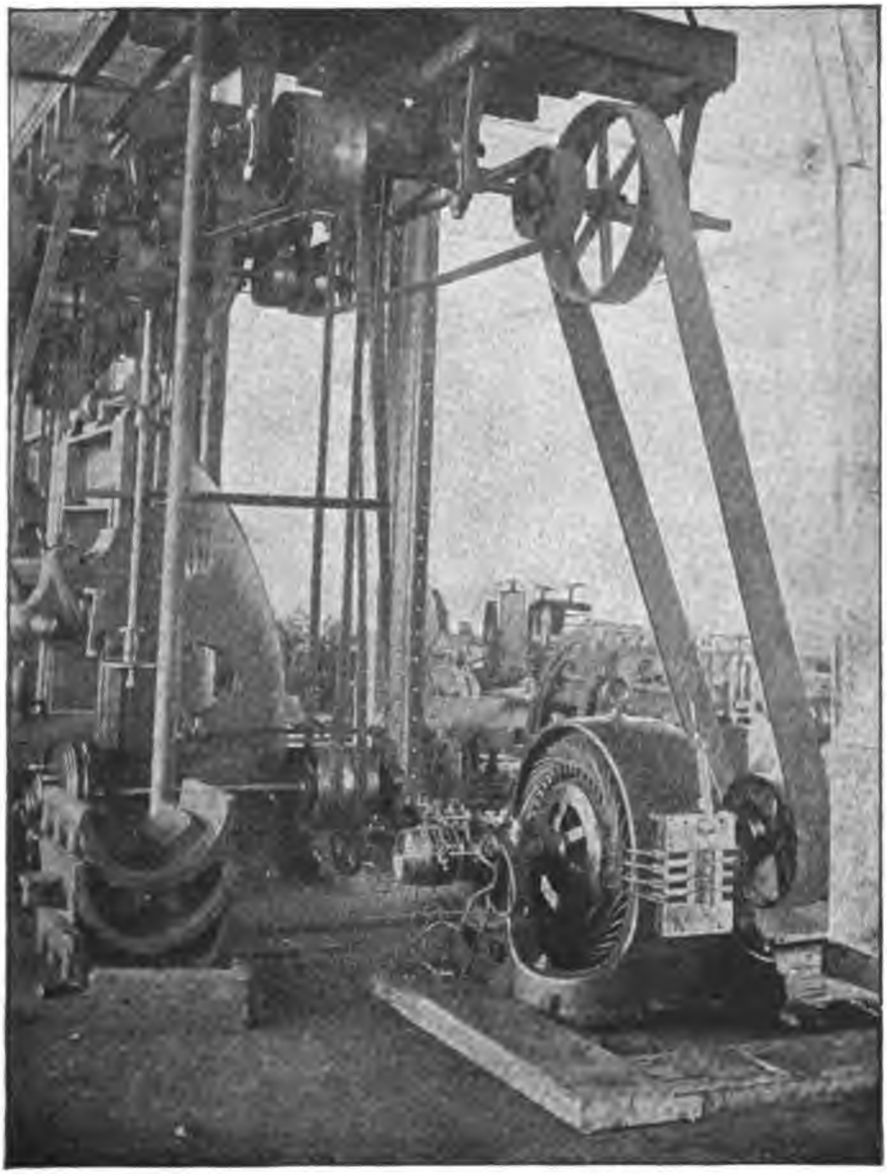


Fig. 390—A 50-H. P. Type B, Tesla Motor Driving Heavy Machinery in the Westinghouse Shops.

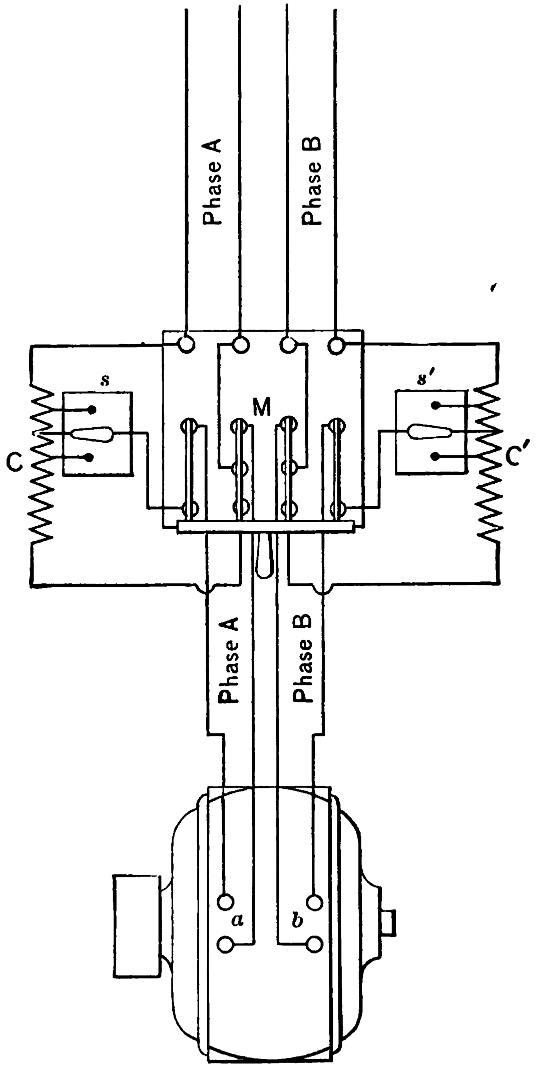


Fig. 389—Connections of "Westinghouse" Auto-Starter.

ting out the coils C and C′, and bringing full pressure upon the motor.

The preceding induction motors are also constructed for triphase circuits by the Westinghouse Company, the difference consisting entirely in the field winding. The magnetic field is then made to rotate by the interaction of three triphase currents, instead of two diphase currents.

Fig. 390, shows another form of Westinghouse two-phase induction motor of 50 H. P. In this machine the diphase-alternating currents are led to the rotating part or rotor, through four collector rings on the end of the rotating shaft. This produces a rotating field around the periphery of the rotor, and sets up induced currents in the stationary surrounding ring or stator. The large switch is for cutting out resistances in the stator circuits, when the machine has been brought up to speed.

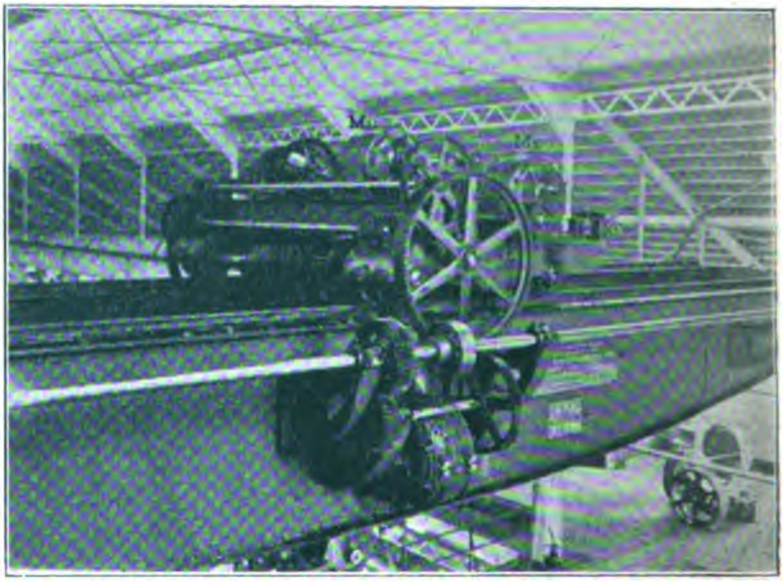


Fig. 391—Crane Equipped with “ Westinghouse ” Type “ C ” 2-Phase Motor.

Fig. 391 A, shows a crane equipped with Westinghouse Electric Company's Diphase Motors of the "C" type. M_1, M_2, M_3, perform the same functions as those described in relation to Fig. C is an auto-converter for use with M_2. at starting.

The efficiency of induction motors is usually quite as good as the efficiency of continuous-current motors of the same power. Thus, a one-horse power induction motor when fully loaded usually has about 75 per cent. efficiency; a 10 H. P. motor, 80 per cent; and a 50 H. P. motor, 90 per cent.

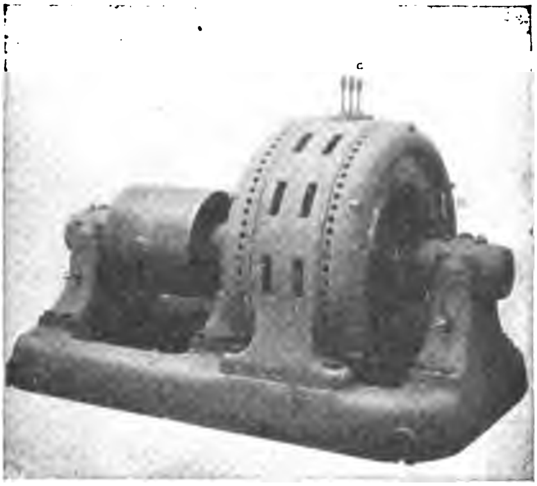


Fig. 392—"General Electric" Triphase Induction Motor.

Fig 392, shows a General Electric Company's triphase induction motor. This machine produces 12 rotating magnetic poles; that is to say, an arrangement of 12 alternating poles, each pole being situated 30° distant in the field frame from the adjoining poles. It makes 600 revolutions per minute at no load, so that it is intended for a circuit having 12 x 600 = 7,200 alternations per minute; i.e., 60 cycles per second. It is wound for 3,000 volts, and for a delivery of 100 K. W. This type of motor is employed in driving mining machinery in South Africa. The three terminals a, b and c, are for the reception of the three-phase wires.

The starting of these induction motors is effected with the aid of the handle H. This handle when pressed forward towards the machine, causes a rotating collar to enter certain contacts and thereby, short-circuit certain resistances which are carried around with the armature.

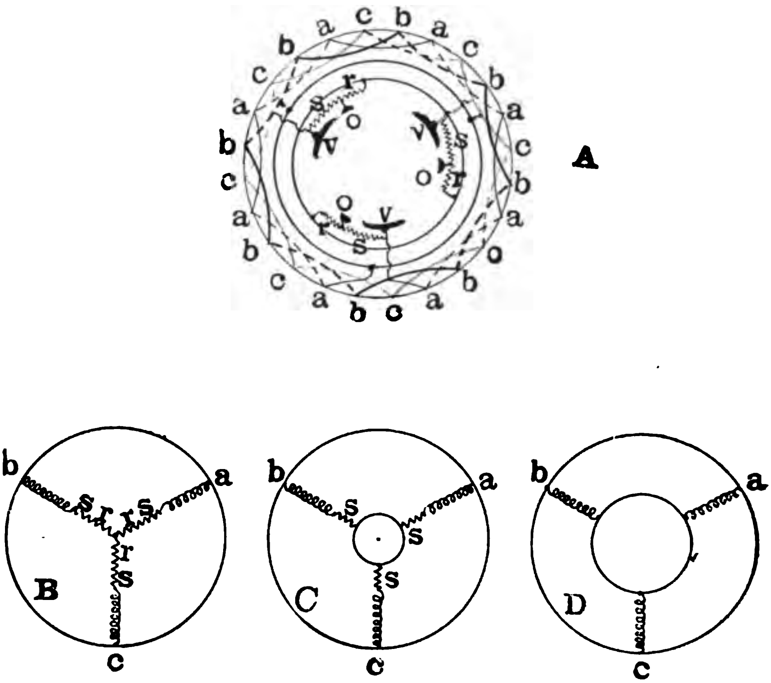


Fig. 393—Diagram of "General Electric" Induction Motor Armature Connections.

The arrangement of these resistances is represented diagrammatically in Fig. 393. At A, is shown the general arrangement of the armature winding. It will be seen that there are three circuits a, b and c, connected between a pair of conducting rings. In each circuit is placed a pair of resistances *r*, *s*, so that there are three triphase windings which start from one ring, and after traversing these resistances, terminate at the other ring. The collar on the armature shaft which is pressed forward by the handle H, in Fig. 392, establishes connection first with the three shoes o, o, o, and then with the three shoes v, v, v. By this means the resistances are cut out in two successive steps. At B, in the figure is a diagram of three triphase armature circuits connected to a common point or ring by resistances r s. At C, the inner resistances r, have been cut out by the first step of the collar. At D, the outer resistances s, have been cut out by the second step of the collar. B, shows the condition of the armature at starting, and D, when running.

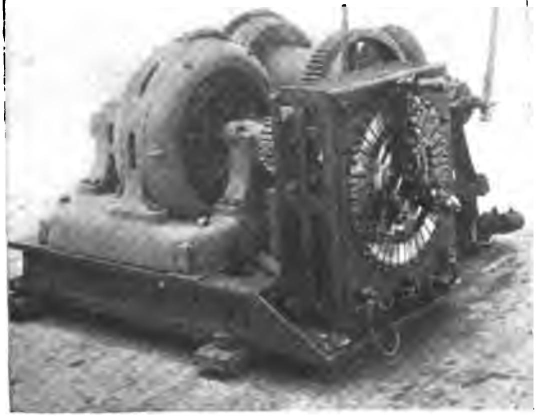


Fig. 394—"General Electric" Triphase 8-pole, 10 H.-P. Induction Motor.

Fig. 358, shows a General Electric Company's triphase eight-pole 10 H. P. induction motor running at 900 revolutions per minute on a 60-cycle-per-second circuit at Bulawayo Mines, South Africa.

The rheostat which is seen in front of the machine controls both field and armature circuits. When at the off position the field circuits are broken at the inner rings which are divided into three segments. On turning the rheostat handle to start the motor, the primary or field circuits are first closed at the inner rings, thus establishing the rotating field in the motor, and the full resistance is inserted in the three armature circuits. This resistance is cut out in successive steps in order to regulate the torque and speed.

In small motors of 10 H. P. or less, there is usually only a single set of resistances s, and but two positions of the starting lever instead of three.

A General Electric Company's triphase induction motor, disassembled, is shown in Fig. 395. F, is the laminated field frame, wound with three sets of coils, connected to the triphase terminals a, b, c, and producing a rotating magnetic field. A, is the armature, having a laminated core and triphase winding, as represented in Fig. 393. C, is the sliding collar, which is moved into and out of spring contacts, by the lever L, under the control of the handle H.

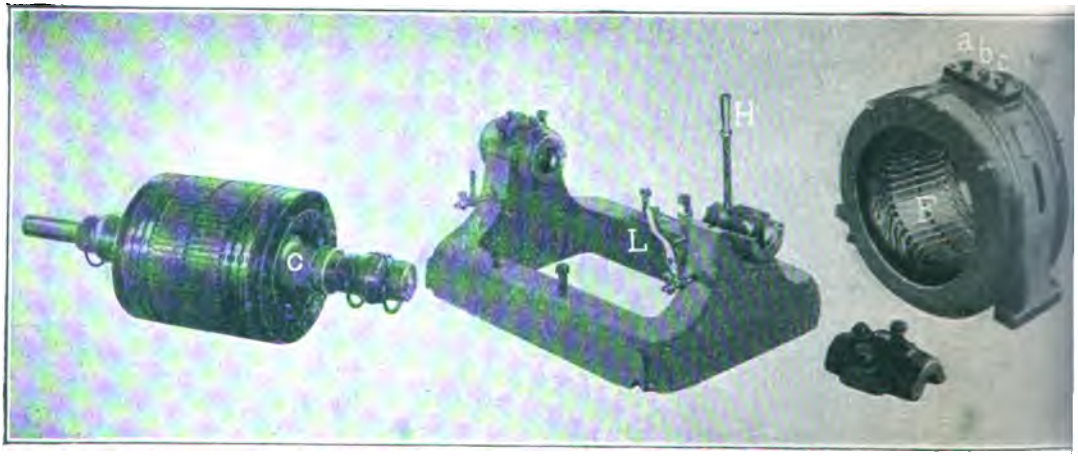


Fig. 395—A "General Electric" Triphase Induction Motor Disassembled.

The dimensions of these motors are given in Fig. 396, up to 5 H. P. and in Fig. 397, up to 150 H. P. in connection with the accompanying table.

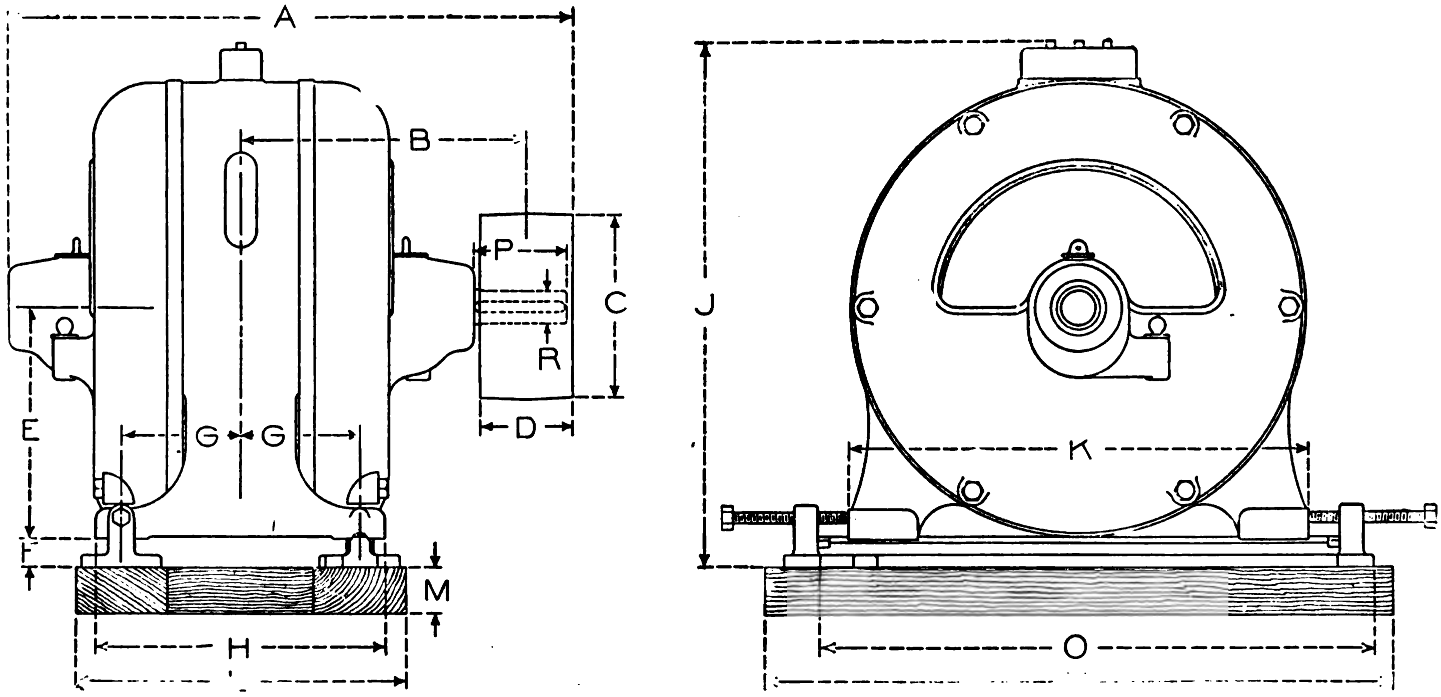


Fig. 396—Dimensions of "General Electric" Triphase Induction Motors.

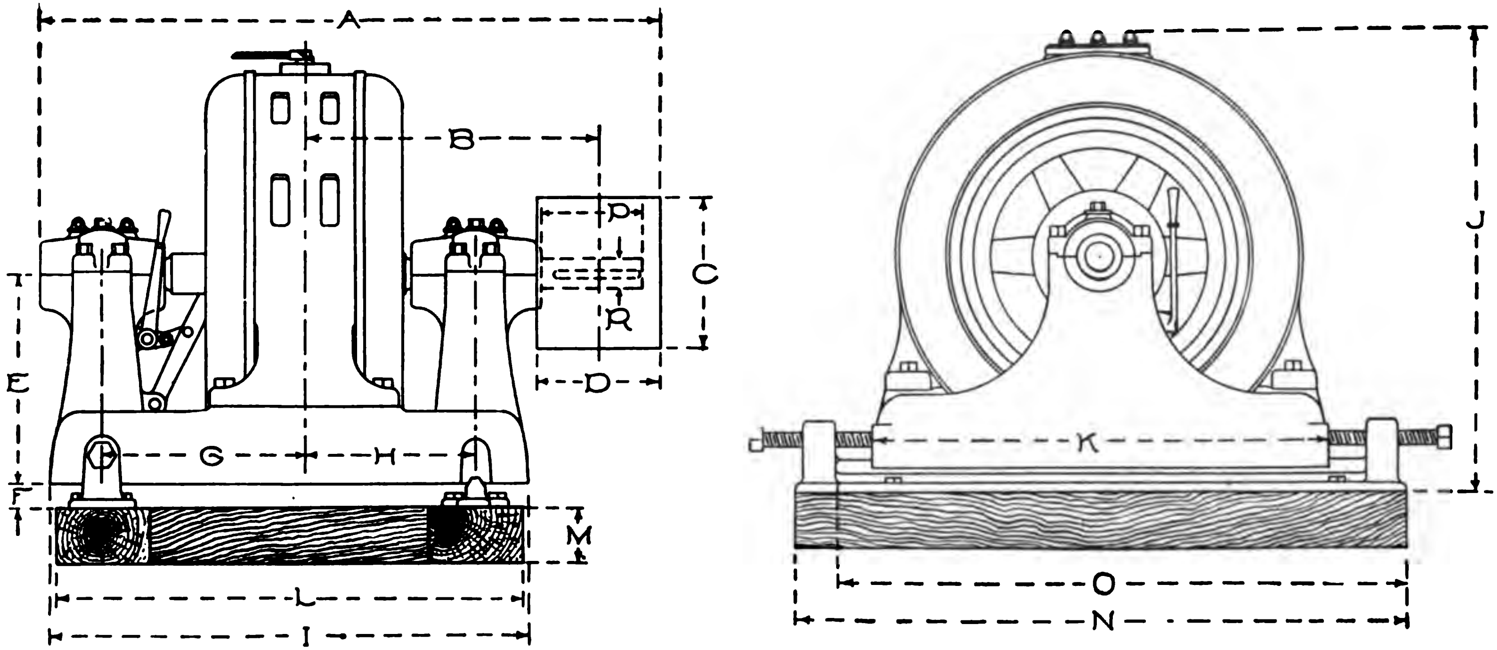


Fig. 307—Dimensions of "General Electric" Triphase Induction Motors.

TABLE OF GENERAL ELECTRIC TRIPHASE INDUCTION MOTORS 1-5 H. P. 60 CYCLES.

CLASSIFICATION.					WEIGHT.		A	B	C	D	E	F	G	H	J	K	L	M	N	P	R
Type.	Poles.	H. P.	Speed.	Form.	With Rails.	Without Rails.															
I	4	1	1800	B	175	160	$16\frac{9}{16}$	$8\frac{5}{16}$	$4\frac{1}{2}$	$2\frac{1}{2}$	6	$\frac{5}{16}$	$4\frac{1}{4}$	$10\frac{1}{2}$	$14\frac{7}{16}$	12	$11\frac{3}{4}$	2	$19\frac{3}{8}$	$2\frac{7}{16}$	$\frac{7}{8}$
I	4	2	1800	C	220	205	$18\frac{1}{2}$	$9\frac{3}{8}$	$4\frac{1}{2}$	$2\frac{1}{2}$	7	$\frac{5}{16}$	$4\frac{3}{8}$	11	$16\frac{3}{8}$	$13\frac{1}{2}$	$12\frac{3}{4}$	2	$20\frac{1}{2}$	$2\frac{5}{8}$	$\frac{7}{8}$
I	4	3	1800	A	220	205	$18\frac{1}{2}$	$9\frac{3}{8}$	$4\frac{1}{2}$	$2\frac{1}{2}$	7	$\frac{5}{16}$	$4\frac{3}{8}$	11	$16\frac{3}{8}$	$13\frac{1}{2}$	$12\frac{3}{4}$	2	$20\frac{1}{2}$	$2\frac{5}{8}$	$\frac{7}{8}$
	6	5	1200	E	490	470	$24\frac{1}{4}$	$12\frac{1}{4}$	8	4	10	$1\frac{1}{8}$	$5\frac{1}{8}$	$12\frac{1}{2}$	$22\frac{5}{8}$	$19\frac{3}{4}$	$14\frac{1}{4}$	2	$25\frac{1}{2}$	$4\frac{1}{16}$	$1\frac{7}{16}$

TABLE OF GENERAL ELECTRIC COMPANY'S TRIPHASE INDUCTION MOTORS 10–150 H. P. 60 CYCLES PER SECOND.

CLASSIFICATION.					WEIGHT.																	
Type.	Poles.	H. P.	Speed.	Form.	With Rails.	Without Rails.	A	B	C	D	E	F	G	H	I	J	K	L	M	N	P	R
I	6	10	1200	A	825	775	39⅝	18⅝	8	6	10	1⅝	14¼	11½	30¾	22⅝	22	32¾	3	30½	5¼	1 11/16
I	8	15	900	C	1,200	1,125	43	20¼	13	7	12	1⅞	15	12½	33½	27 7/16	27½	36½	4	42	6	2
I	8	20	900	A	1,825	1,700	43⅞	21⅞	13	7	15½	2⅛	13¾	13¾	34½	34½	34	36½	4	48	5¼	2
I	8	30	900	A	2,575	2,450	57¾	29	13	9	15½	2⅛	18	18	43¾	35¾	34¾	45	4	48	8¼	2 11/16
I	10	50	720	B	5,150	4,875	65⅝	31	16	13	22	2½	21½	18	50½	47¾	48	49½	6	64½	11¼	3½
I	12	75	600	A	7,000	6,450	71¾	33	19	17	26	3	22¼	18⅛	50¾	56⅛	57	52¾	8	78½	11¾	4
I	12	100	600	B	7,925	7,875	79¾	38¼	19	21	26	3	23	20¾	55¾	56⅛	58	55¾	8	78½	16 7/16	4
I	12	150	600	A	9,950	9,400	91	44½	28	21	28½	3	26½	25	64	59⅛	58	63½	8	78	18	5

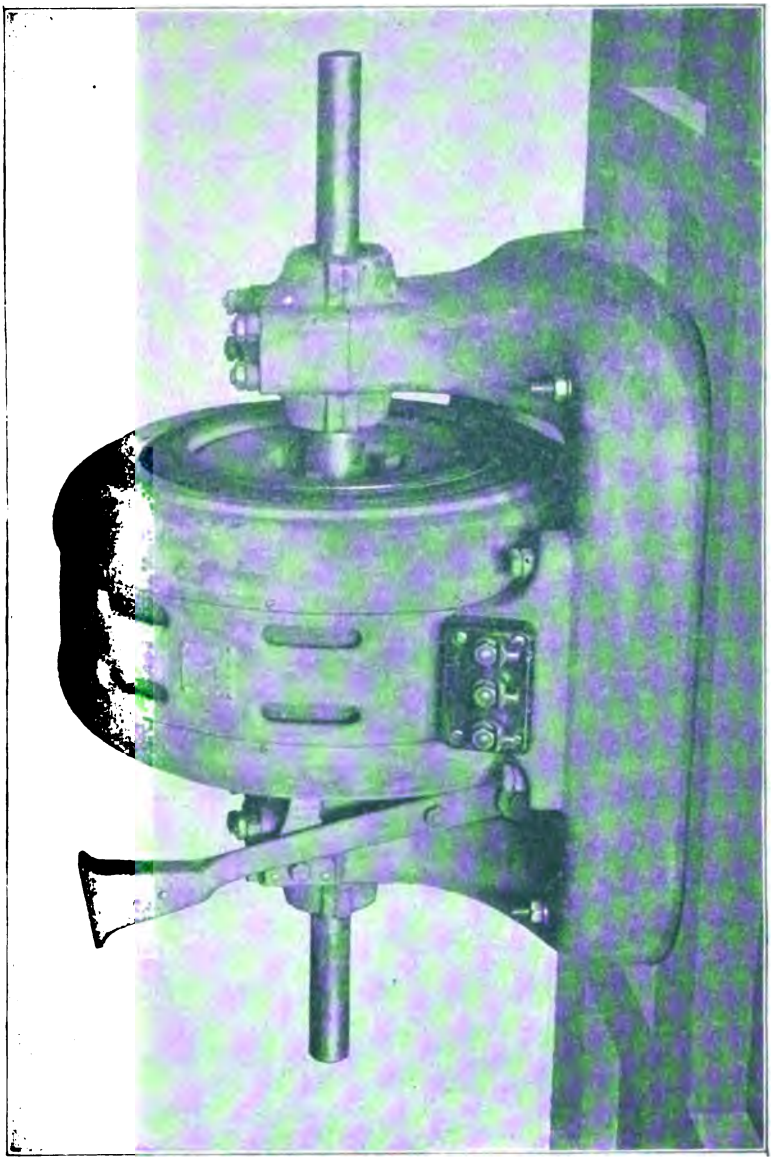


Fig. 398—A "General Electric" Triphase Induction Motor, Inverted Form.

TABLE OF GENERAL ELECTRIC COMPANY'S TRIPHASE INDUCTION MOTORS 10–150 H. P. 60 CYCLES PER SECOND.

CLASSIFICATION.					WEIGHT.		A	B	C	D	E	F	G	H	I	J	K	L	M	N	P	R
Type.	Poles.	H. P.	Speed.	Form.	With Rails.	With-out Rails.																
I	6	10	1200	A	825	775	39⅝	18⅝	8	6	10	1⅝	14¼	11½	30¾	22⅝	22	32¾	3	30½	5½	$1\frac{13}{16}$
I	8	15	900	C	1,200	1,125	43	20¼	13	7	12	1⅞	15	12½	33⅛	$27\frac{7}{16}$	27½	36½	4	42	6	2
I	8	20	900	A	1,825	1,700	43⅞	21⅞	13	7	15½	2⅛	18¾	13¾	34½	34⅛	34	36½	4	48	5¼	2
I	8	30	900	A	2,575	2,450	57¾	29	13	9	15½	2⅛	18	18	43¾	35¾	34¾	45	4	48	8¼	$2\frac{11}{16}$
I	10	50	720	B	5,150	4,875	65⅝	31	16	13	22	2¼	21½	18	50½	47¾	48	49½	6	64½	11¼	3½
I	12	75	600	A	7,000	6,450	71¾	33	19	17	26	3	22¼	18⅛	50¾	56⅛	57	52¾	8	78½	11¾	4
I	12	100	600	B	7,925	7,375	79¾	38¼	19	21	26	3	23	20¾	53¾	56⅛	58	55¾	8	78½	$16\frac{7}{16}$	4
I	12	150	600	A	9,950	9,400	91	44⅛	28	21	28½	3	26½	25	64	59⅛	58	63½	8	78	18	5

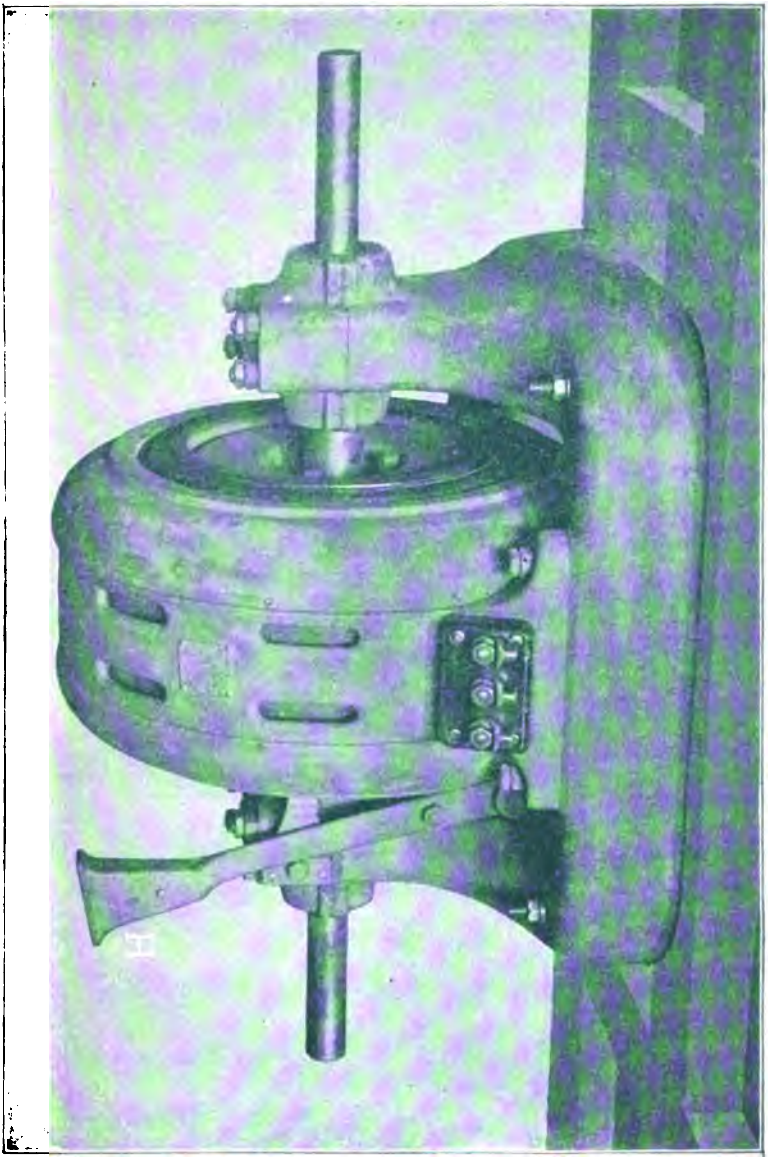


Fig. 398—A "General Electric" Triphase Induction Motor, Inverted Form.

Fig. 398, shows a General Electric Company's triphase induction motor, supported from a ceiling beam in a position suitable for driving shafting. Here, the starting handle H, is intended to be operated by a lever from the floor. This machine has 12 poles, and makes 600 revolutions per minute. It is, therefore, intended for a 60-cycle circuit. It supplies 110 H. P. at full load. This type of motor is advantageous for use in mills and factories, since it occupies no floor space and is readily belted to countershafting. Fig. 399 gives the dimension of these ceiling motors in connection with the table on page 551.

Fig. 400, shows a General Electric Company's triphase induction motor, connected to a duplex sinking pump, capable of delivering 150 gallons per minute against 300 feet head. This motor is so arranged that it can be operated when entirely submerged in water and is suitable for mining work.

Fig. 401, shows a General Electric Company's uniphase induction motor weighing 350 lbs. This is a 2 H. P. machine, with 8 poles, making 1870 revolutions per minute on light load, corresponding to 12,000 alternations per minute or a frequency of 125 cycles per second. Being a uniphase motor, it would not be capable of starting when connected with uniphase mains, but it is started by connecting two resistances in series across the 104 volt mains, one resistance being non-inductive, and the other being inductive. This produces a difference of phase in the pressure at the terminals of the two resistances, and a wire being led from their junction to the middle terminal of the motor serves to provide a difference of phase to the motor in order to start it.

The current taken by an induction motor when running light is usually about $\frac{1}{3}$d of the current it takes when loaded, but as this light-loaded current is much out of step with the pressure, it only represents a fraction of the power corresponding to the product of the volts and amperes. As this current requires a correspondingly large current from the generator even if attended with comparatively little power,

DIMENSIONS OF THREE-PHASE INDUCTION MOTORS TYPE I INVERTED

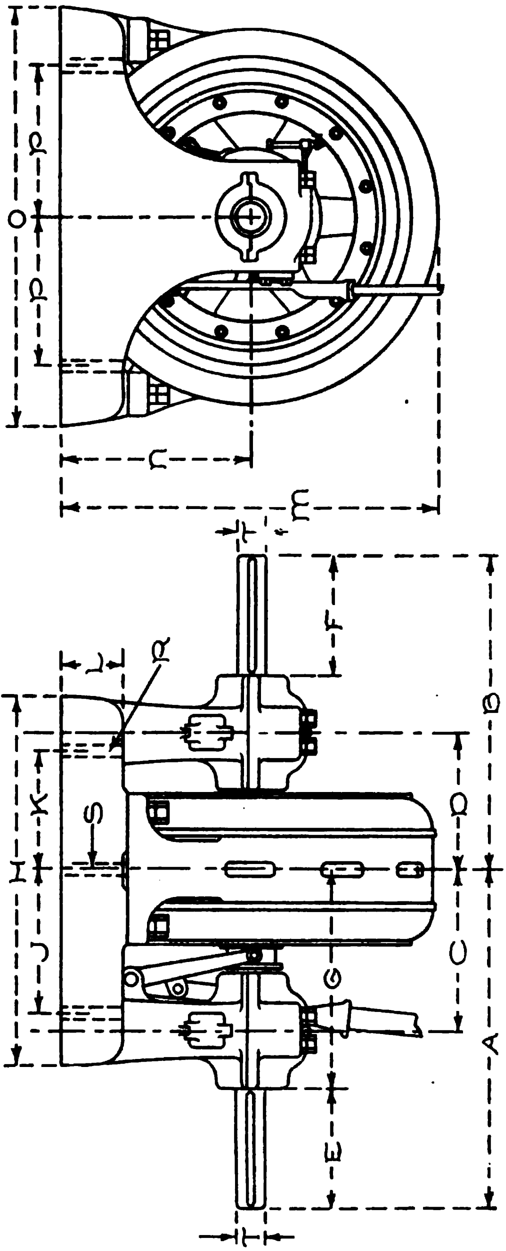


Fig. 399

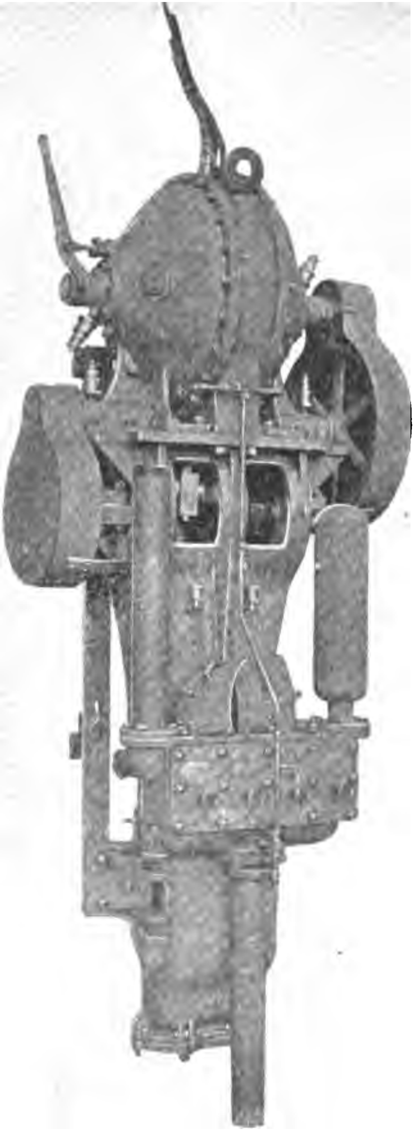


Fig. 400—A "General Electric" Waterproof Pumping Induction Motor.

TABLE OF GENERAL ELECTRIC COMPANY'S INVERTED TYPE OF TRIPHASE MOTORS.

Type	Poles	H. P.	Speed.	Form	Weight	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Size of Bolt		T	Cycles
																					R	S		
I	8	75	600	A	6300	46	42½	26	22½	12	12	34	59½	24¼	20¾	8¾	44⅝	23	48	19	1½		4	40
I	8	20	900	A	1800	28¼	28¼	13¾	13¾	10	10	18¼	34½	13¾	13¾	5¾	30⅜	15½	34	12	1⅛		2¼	60
I	8	30	900	A	2500		31⅝	17⅞	17⅞		8	23⅛	43¼	17⅞	17⅞	6	30⅜	15½	34½	12	1¼		2 11/16	60
I	10	50	720	A	4800	41	37½	21½	18	12⅝	12⅝	28⅜	50½	21½	18	7¾	43⅝	22	48	16⅝	1½		3½	60
I	12	75	600	A	6400	46¾	43	22¼	18½	16½	16½	30¼	50¾	22¼	18½	8¾	51¾	26	57	20	1½		4	60
I	12	100	600	A	7300	51½	49¼	23	20¾	20½	20½	31	55¾	23	20¾	8¾	51¾	26	58	21½	2		4	60
I	8	150	600	A	11800	53⅝	52⅛	27⅞	26⅝	16	16	37⅝	67	27⅞	26⅝	7	56 11/16	29½	66	31	2	2	5	40

it is advisable to install induction motors in such a manner that they may run conveniently near full load, when the current and pressure will be nearly in step. The current strengths required to start the General Electric Company's induction motors is stated in the accompanying table.

CURRENT TAKEN BY THREE-PHASE INDUCTION MOTORS AT 110 VOLTS.

H. P. OF MOTOR.	FULL-LOAD CURRENT.	Starting Current at 150 per cent. of Full Load Torque.	Starting Current at Full Load Torque.
1	6.3	19	
2	12	36	
3	18	54	
5	28	42–84	28
10	54	70	54
15	81	120	81
20	112	167	112
30	168	252	168
50	268	400	268
75	390	585	390
100	550	825	550
150	780	1180	780

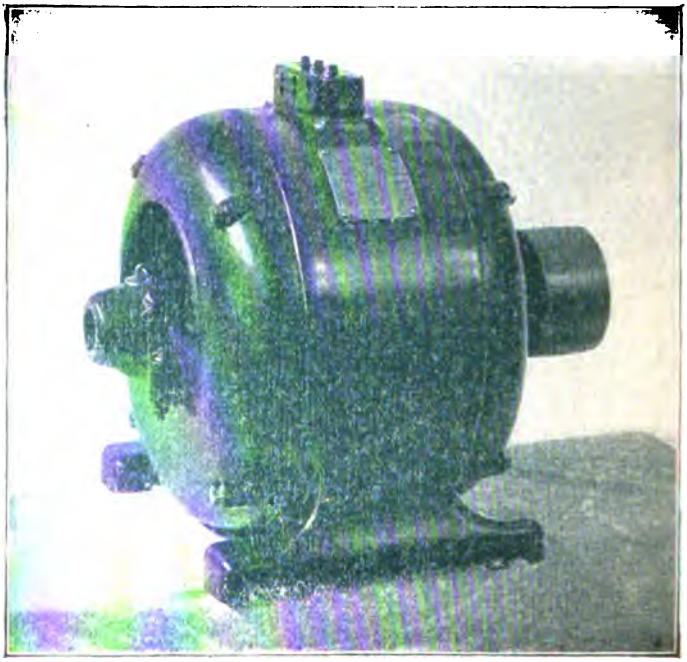


Fig. 401—"General Electric" Uniphase Induction **Motor.**

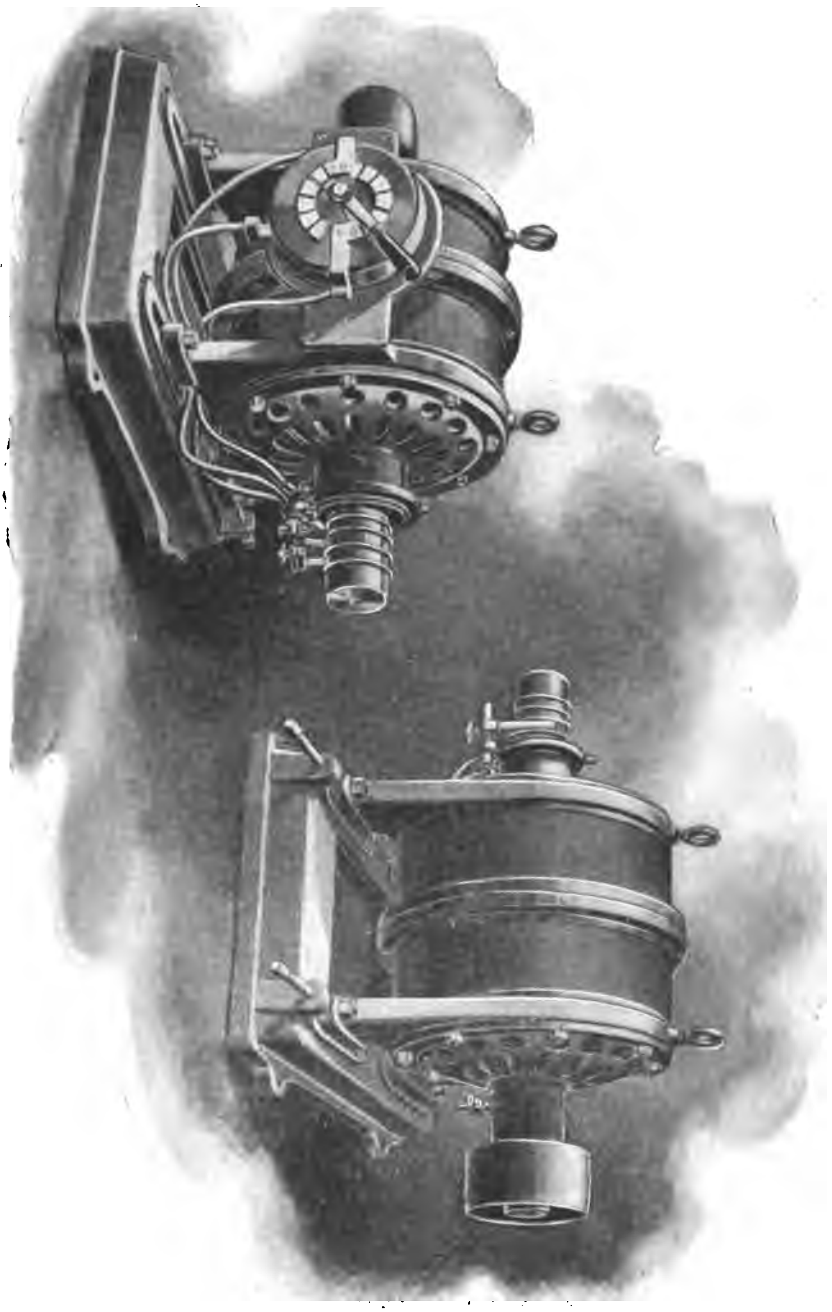


Fig. 402—S. K. C. Two-Phase Motors.

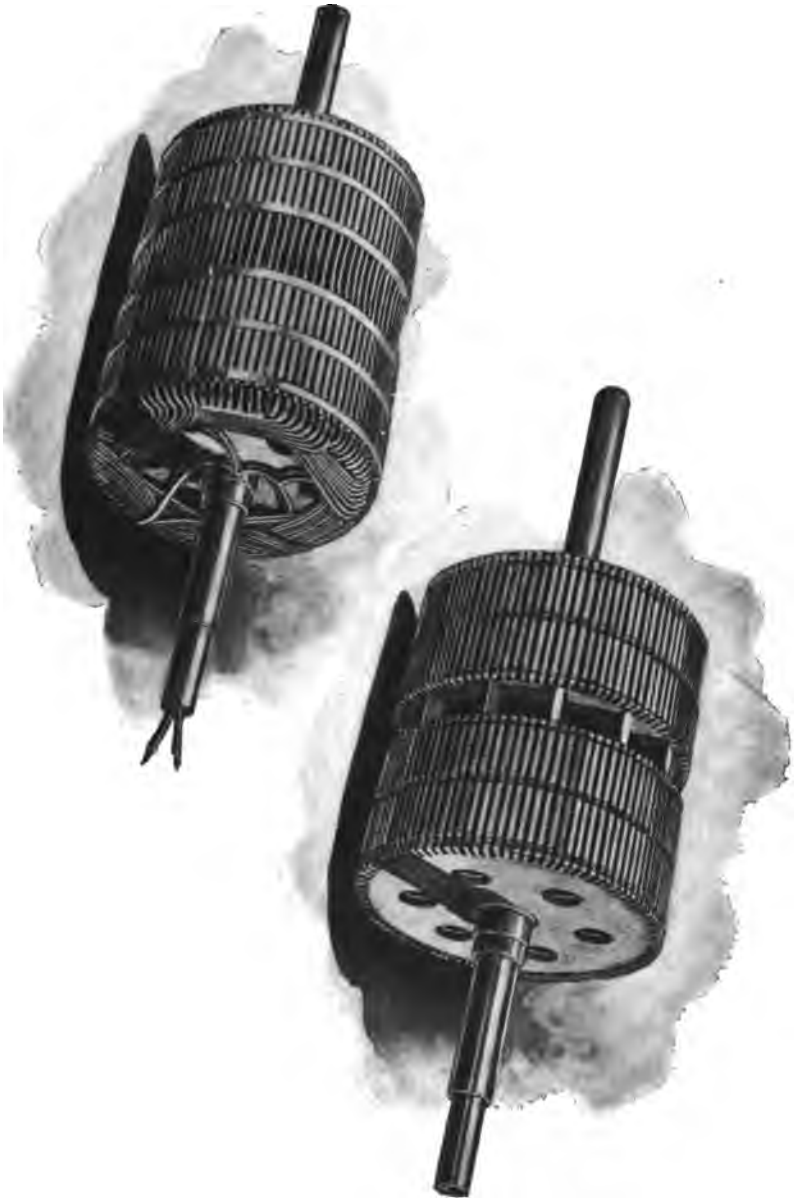


Fig. 404—Armatures of S. K. C. Two-Phase Motors, Wound and Unwound.

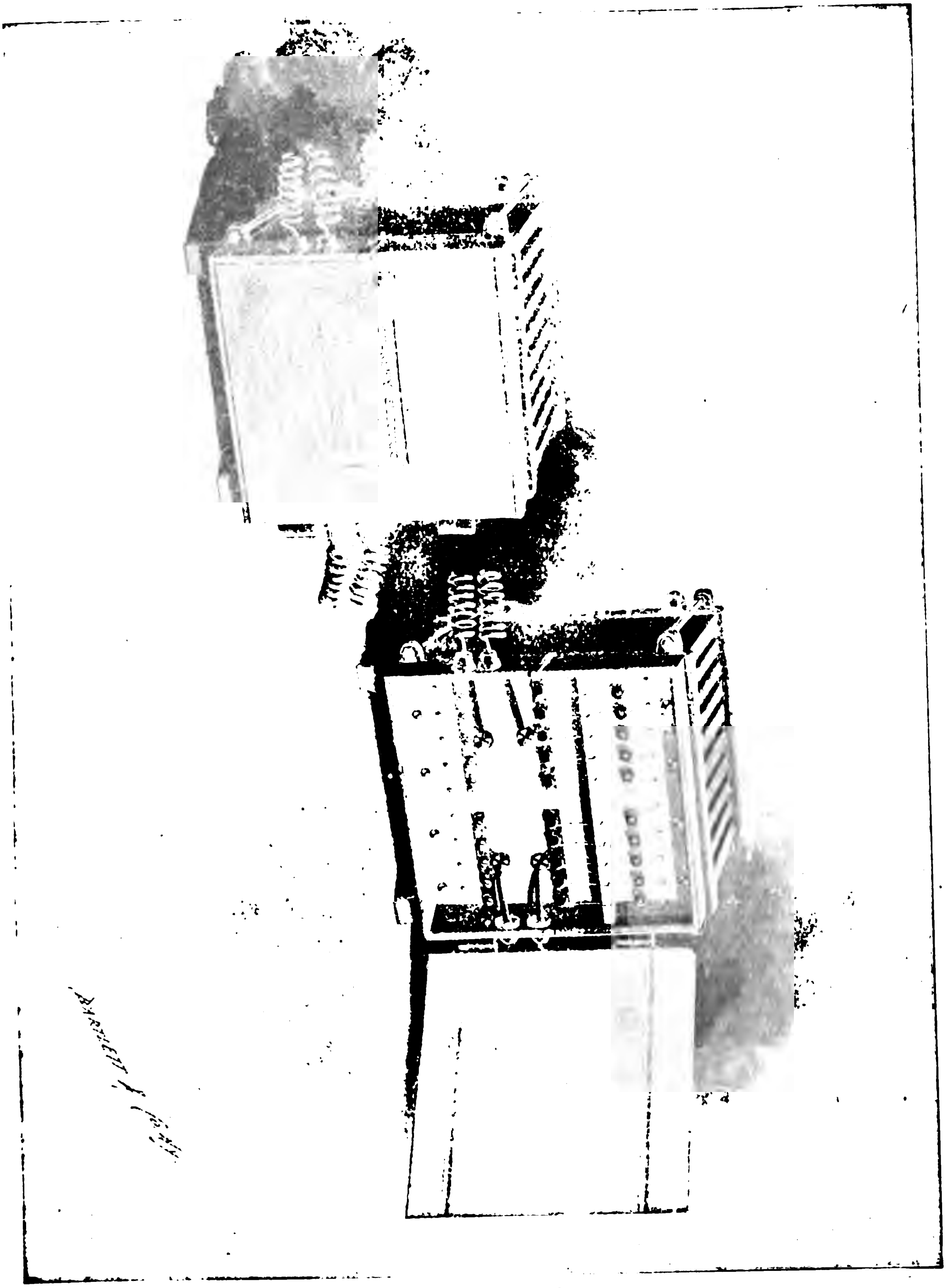


Fig. 405—S. K. C. Condenser.

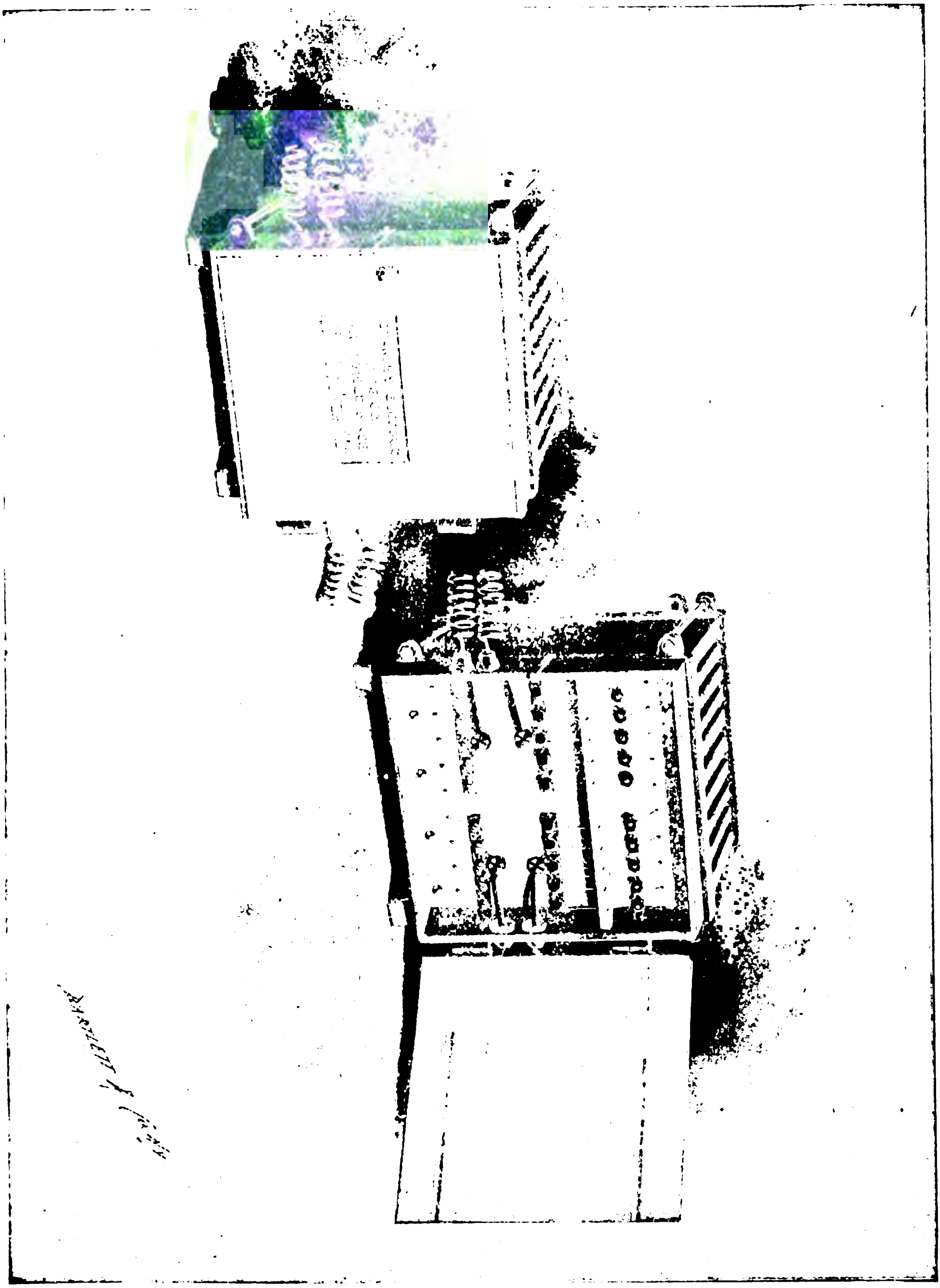


Fig. 405—S. K. C. Condenser.

Fig. 402, shows a front and rear view of the Stanley Electric Company's standard two-phase induction motor. Here, one of the diphase currents is supplied to one half of the stator winding, and the other diphase current is supplied to the other half. The rotor, which is subjected to the magnetic action of both portions of the stator, has currents induced in its windings. These produce a magnetic field which starts the motor. A switch, whose handle is shown, is for the purpose of cutting out resistance from the rotor circuits as the machine is brought up to speed.

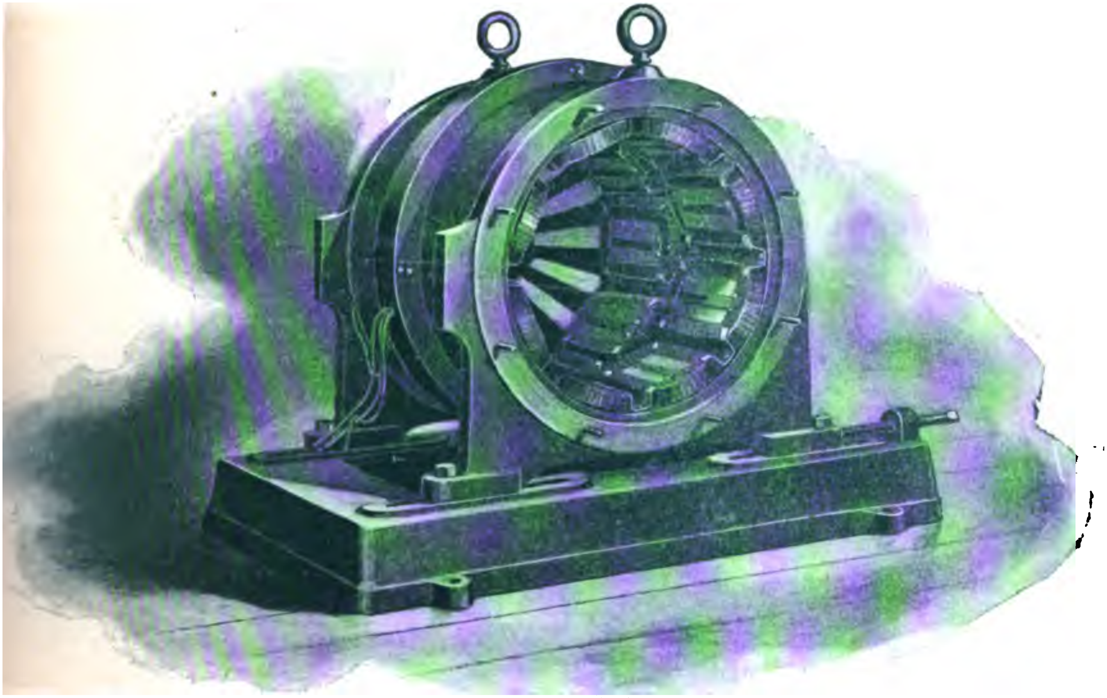


Fig. 403—Field of S. K. C. Two-Phase Motor.

Fig. 403, shows the interior of the stator or stationary field of this machine. This is composed of a laminated cylinder in two halves. One half is wound with one set of coils in series and the other half is wound with a second set, the two sets overlapping; *i. e.*, not placed opposite, but alternate in position as shown in the figure. One set of coils is connected to one circuit and the other set of coils to the other circuit of the diphase system, the pressure at terminals being approximately 500 volts in each circuit.

It will be seen that there is a copper bar lying across the centre of each pole-piece. Each of these bars forms a part of a local circuit. If these short-circuited bars were removed, the currents flowing in the armature windings would be considerably retarded. The proximity between the fixed closed circuits of the copper bars and the revolving closed circuits of the armature serves to largely reduce the self-induction of the latter, and thereby to increase the effective torque of the motor.

Fig. 404, shows a rotor armature both in the wound and unwound condition. It will be seen that the core is made in two portions, one for each half of the stator frame. The winding is carried across so as to cover both portions, so that the currents induced in one portion may pass through the other. The ends of these windings are brought through a hollow shaft and are connected to collector rings.

Induction motors always tend to retard the current which they receive; or, in other words, to cause the waves of current to lag behind the waves of alternating E. M. F., or pressure which produce them. This tendency to retard the phase of the current increases with the frequency of the alternation, being more noticeable at a frequency of, say, 125 cycles per second, than at a frequency of, say, 60 cycles per second. To neutralize this tendency as far as possible, condensers are connected across the terminals of the S. K. C. motors, since a condenser inserted in an alternating-current circuit tends to advance the current, or make the waves of current flow ahead of the waves of the E. M. F. The neutralization of the lagging tendency in the motor by the leading tendency in the condensers, considerably improves the regulation of the distribution system, and reduces the amount of current required to operate the motor.

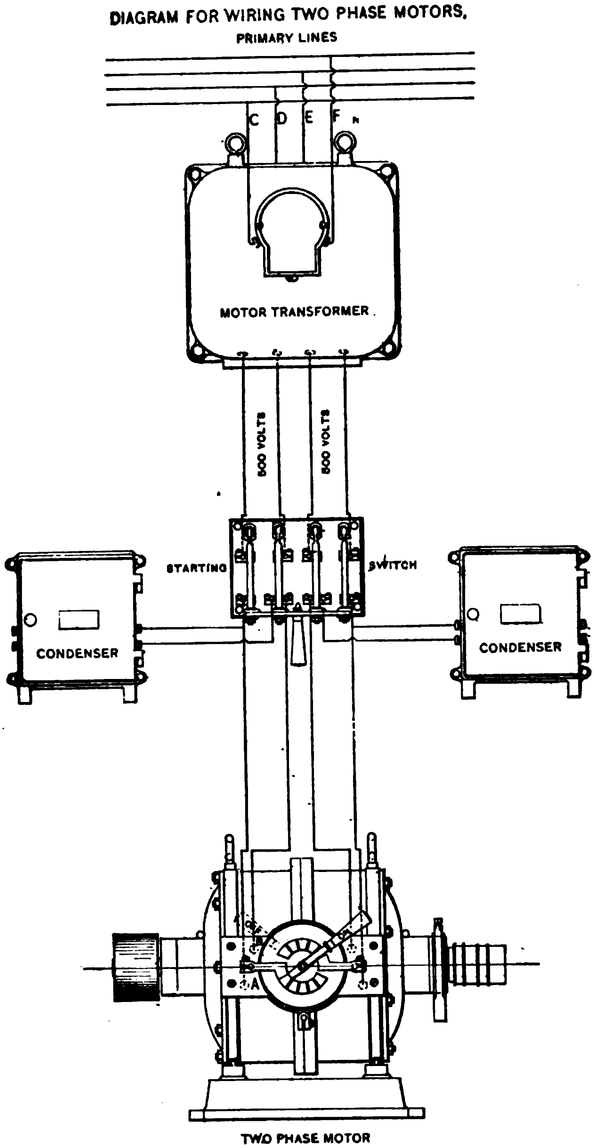


Fig. 406—Connection of S. K. C. Two-Phase Motors.

PARTICULARS OF "S. K. C." DIPHASE MOTORS.

Motor.	H. P.	Speed R.P.M.	Belt Sp. F. P. M.	Pulley		Bearings		Weight Complete	Space Occupied			F	G	H	J	K	L
				Diam.	Face	Bore.	Length		C	D	E						
2A	1	2400	1885	3	2½	¾	2¼	260	19¾	21⅝	15¼	14½	15½	16⅝	10¾	6¼	2¾
2B	1	1850	1455	3	2½	¾	2¼	290	21½	21⅝	15¼	15¼	16¼	16⅝	12½	6¼	2¾
4A	2	2400	2515	4	2½	1	3	340	22¾	23⅝	17⅛	14½	15½	18⅝	11⅝	7¼	2¾
4B	2	1850	1840	4	2½	1	3	375	2 1	23⅝	17⅛	16½	17½	18⅝	13¾	7¼	2¾
6A	3	1840	2410	5	3¾	1¼	3¾	625	2 8$\frac{1}{16}$	2 4½	21$\frac{3}{16}$	16½	17¼	20½	12	9	3½
6B	3	1840	2410	5	3¾	1¼	3¾	660	2 11$\frac{3}{16}$	2 4½	21$\frac{3}{16}$	18¼	19⅝	20½	15⅛	9	3½
8A	5	1850	2905	6	4	1½	4½	870	2 11$\frac{15}{16}$	2 7¼	23⅞	18½	19⅞	23¼	14¼	10	4
8B	5	1850	2905	6	4	1½	4½	920	3 1$\frac{15}{16}$	2 7¼	23⅞	19½	20⅞	23¼	16⅛	10	4
10A	7	1850	2905	6	4	1½	4½	980	3 2$\frac{3}{16}$	2 7¼	23⅞	19½	20⅞	23¼	16½	10	4
10B	7	1850	2905	6	4	1½	4½	1030	3 5$\frac{3}{16}$	2 7¼	23⅞	22½	23⅞	23¼	19½	10	4
12A	10	....	...	.	..	..	..	....	....	....	....	...	....	....	....	....	..
12B	10	....	....	..	..	..	..	....	....	....	....	....	....	....	....	....	..
14A	15	1500	4715	12	6¼	2	6	1600	3 9$\frac{15}{16}$	3 1	2 6$\frac{3}{16}$	2 0½	2 2¼	2 5	19¼	11⅝	7¼
14B	15	1280	4025	12	6¼	2	6	1700	3 11$\frac{15}{16}$	3 1	2 6$\frac{3}{16}$	2 2½	2 4¼	2 5	21¼	11⅝	7¼
16A	20	....	....	..	..	..	..	...	....	....	....	....	...	....	....	....	..
16B	20	....	....	..	..	..	..	....	......	....	......	....	....	....	....	....	..
18A	30	1280	5025	15	8½	2½	7½	2600	4 8$\frac{1}{16}$	3 6	2 11⅝	2 2½	2 4	2 11	22½	14¼	7¼
18B	30	1280	5025	15	8½	2½	7½	2800	4 8$\frac{1}{16}$	3 6	2 11⅝	2 2½	2 4	2 11	22½	14¼	7¼
22A	40	1280	5025	15	10½	3	9	3460	5 4$\frac{1}{16}$	3 9½	3 2⅝	2 4¾	2 6¼	3 1½	2 1	15¼	8¼
22B	40	1280	5025	15	10½	3	9	3500	5 4$\frac{1}{16}$	3 9½	3 2⅝	2 4¾	2 6¼	3 1½	2 1	15¼	8¼

A —16,000 alternations. B — 8,000 alternations.

An S. K. C. condenser suitable for connection across the motor terminals, and, therefore, for sustaining a pressure of 500 volts is shown in Fig. 405, both with the cover closed and with the cover open. The two wires issuing from the apparatus on the left-hand side are connected to one circuit, and the two wires issuing on the right-hand side to the other circuit of the diphase system. The connections are made to the various blocks of the condensers through fuse wires as shown.

Fig. 406, shows the connections of a Stanley Electric Company's two-phase motor with a two-phase system. The switch has four blades and closes both the motor circuits. The dimensions of these motors are shown in the table accompanying Fig. 407. It will be seen that these motors are constructed in standard sizes for two frequencies; namely, 16,000 alternations per minute and 8,000 alternations per minute.

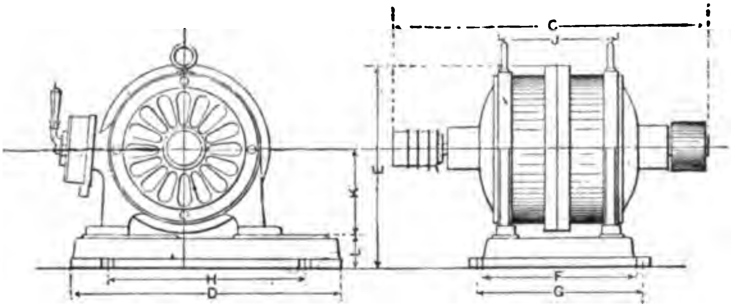


Fig. 407—Dimensions of S. K. C. Two-Phase Motors.

CHAPTER XIII.

REGULATORS FOR ALTERNATING-CURRENT CIRCUITS.

It is sometimes necessary to raise or lower the pressure of an alternating-current circuit, in order to regulate the pressure delivered at its distant end. In alternating-current circuits, this is usually accomplished by means of what are called *alternating-current regulators*, or *induction regulators*. They consist essentially of transformers, in which the primary is excited by being connected directly across the circuit, while the secondary is in series with the circuit, and, therefore, the circuit receives the E. M. F. generated therein.

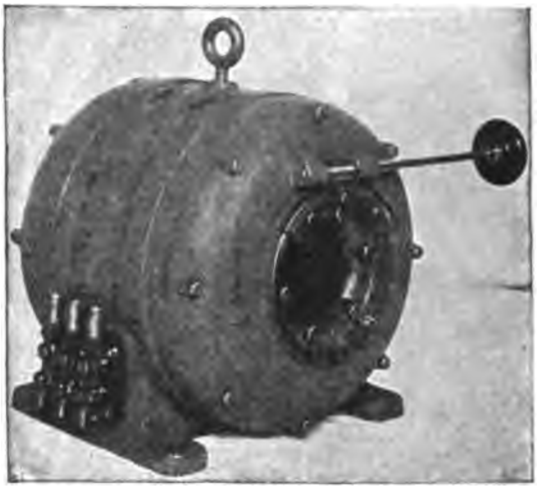


Fig. 408—General Electric Standard Induction Regulator.

Fig. 408, shows a General Electric Company's standard induction regulator, having a capacity of 20 K. W. and for 800 amperes in the secondary circuit. It is intended to raise or lower the voltage in the secondary circuit by 7 volts, as a maximum, so that by moving the interior portion through a range of 120°, with the aid of the handle, a total change of 14 volts will have been effected in the circuit to which the secondary is connected. This machine has 6 poles and is designed for a frequency of 25 cycles per second.

The principle on which an induction regulator operates is illustrated by Fig. 409, which shows the interior of a General Electric Company's small feeder-potential regulator.

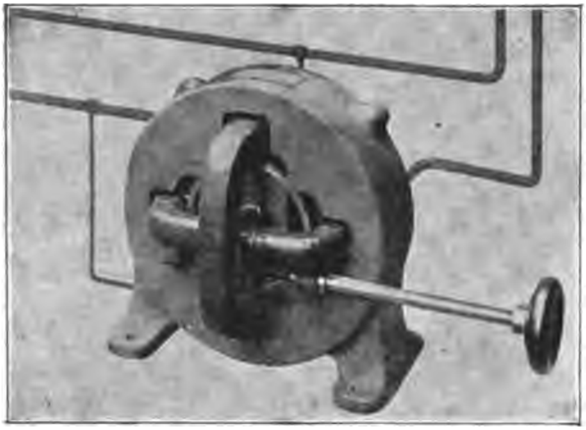


Fig. 409—Feeder Potential Regulator.

Here, there are two coils fixed at right angles to each other in a laminated iron structure. One of these coils is a primary coil and is connected directly across the mains as shown. The other coil is a secondary coil, and is connected in series with the lower main. The magnetic circuit of the primary coil is closed through a laminated core which is capable of being moved about an axis through a limited angular range by the handle. When the core is set at right angles to the primary coil, the total magnetic flux cutting the secondary coil is nil, and no resultant E. M. F. is, therefore, induced in the secondary or the lower main connected with it. When, however, the core is tilted, so as to pass through both coils, a greater or less quantity of the magnetic flux generated by the primary coil is caused to thread through the secondary coil and an E. M. F. is thereby produced in the secondary circuit. Fig. 410, illustrates these connections in greater detail.

A General Electric Company's large induction regulator, of 1,000 H. P. capacity, is shown in Fig. 411. Here, the inner portion is rotated either by hand, or by the aid of a small alternating-current motor. The external frame of the regulator is shown in Fig. 412. The winding of this frame is connected as a primary across the mains, and the interior portion or secondary is connected in series with the mains. The secondary winding is capable of carrying 8,000 amperes,

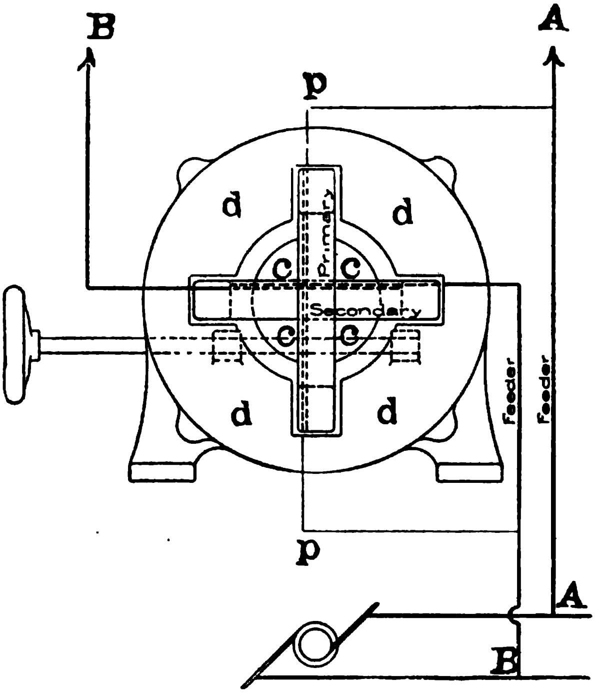


Fig. 410—Diagram of Connections of Feeder-Potential Regulator.

while the pressure induced in the secondary coil, in its maximum position, is about 90 volts. This regulator is in use in the Carborundum Company's works at Niagara Falls.

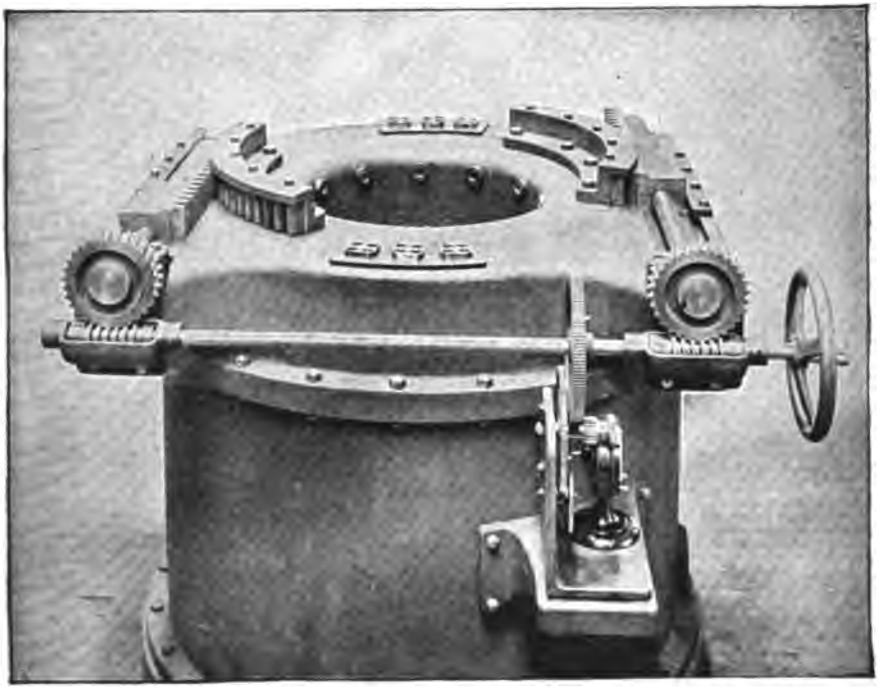


Fig. 411—General Electric 1000-H.P. Induction Regulator.

The Westinghouse Electric Company's Stilwell regulator is shown in Fig. 413. This machine is employed in a feeder to raise or lower its pressure above that of the bus-bars supplying the feeder. It consists essentially of a transformer, whose primary is connected across the bus-bars, while the secondary has a number of different coils which can be introduced into or removed from the circuit of the feeder to be supplied. The pressure is raised by turning the handle so as to include a greater number of secondary turns in the feeder circuit. A diagram of connections is shown in Fig. 414. Here, the dynamo, which is usually a uniphase generator, supplies the lower line directly, and the upper line through the secondary circuit of the regulator. The position of the handle determines how many turns of the secondary winding shall be included in the circuit. By reversing the current through the primary coils, the E. M. F. in the feeder can be reversed, so that it may be either added to or subtracted from the working pressure in the feeder.

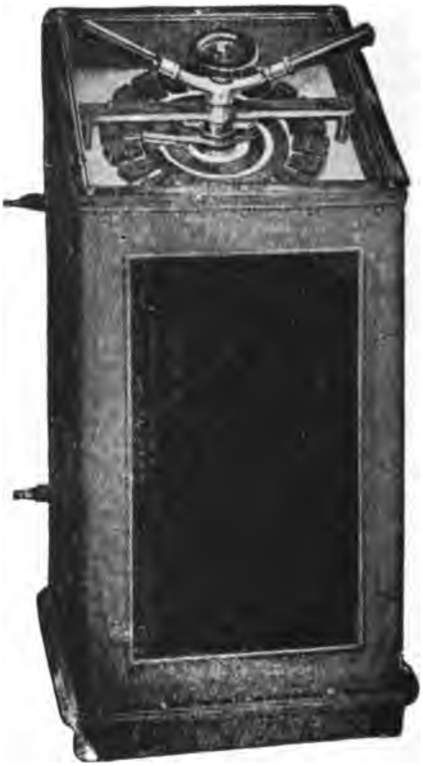


Fig. 413—Westinghouse Stilwell Regulator.

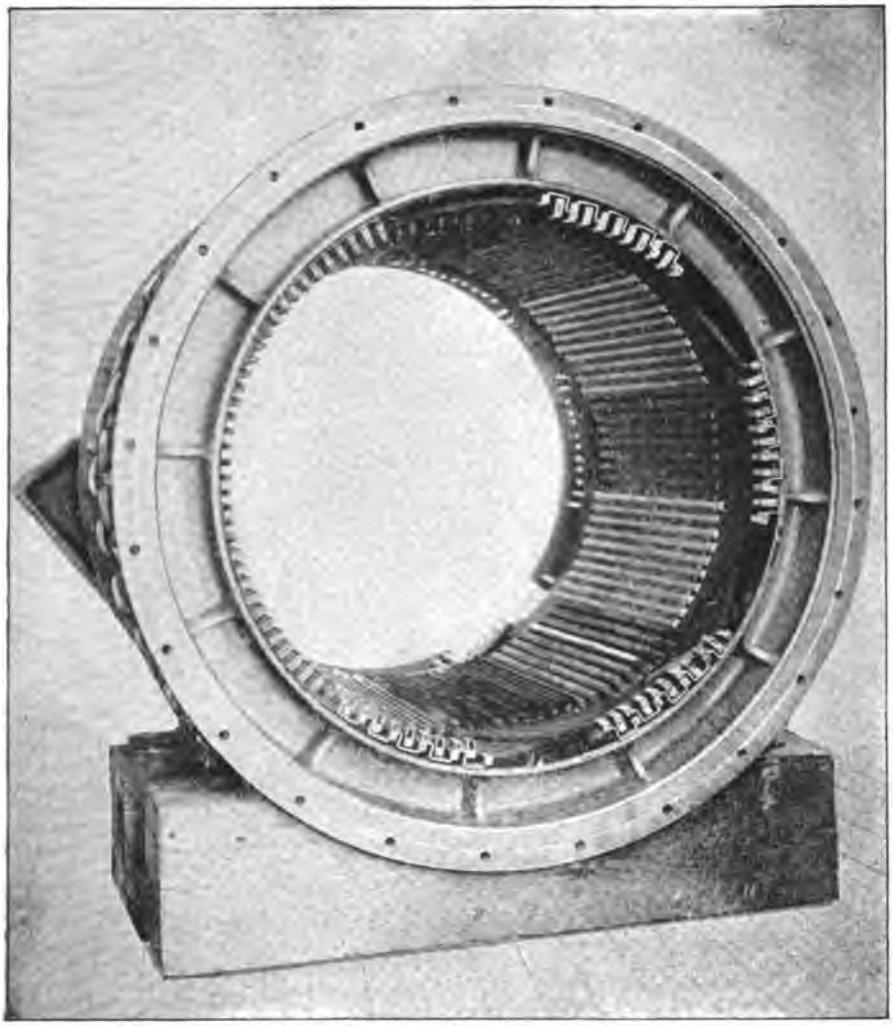


Fig. 412—Frame of General Electric 1000-H.P. Induction Regulator.

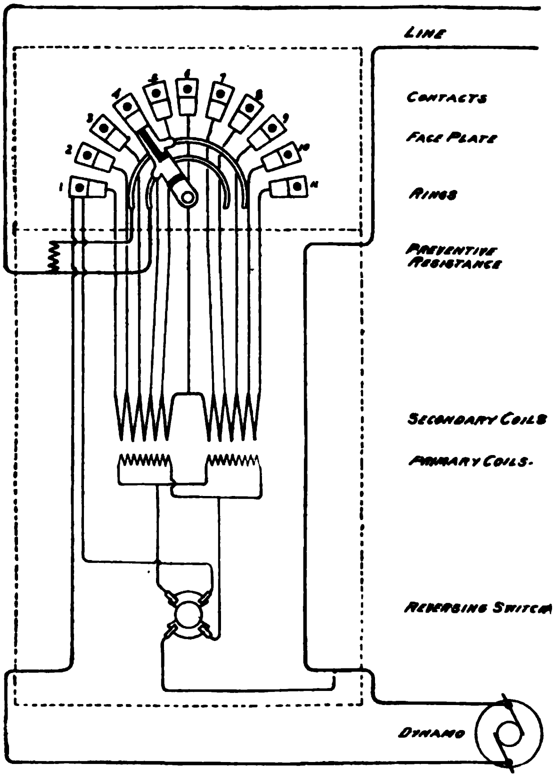


Fig. 414—Internal Connection of the Stillwell Regulator.

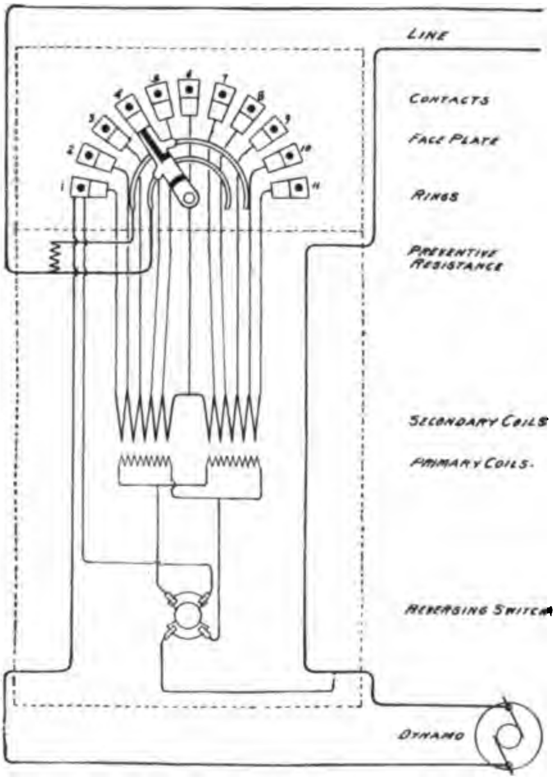


Fig. 414—Internal Connection of the Stillwell Regulator.

.CHAPTER XIV.

SECONDARY GENERATORS.

A *secondary generator* may be defined as an apparatus for obtaining the working pressure of one circuit from a neighboring circuit.

Secondary generators may be divided into three classes; namely:

(1) Those which transform continuous currents at one pressure into continuous currents at another pressure.

(2) Those which transform continuous currents into alternating currents.

(3) Those which transform alternating currents into continuous currents.

The apparatus for effecting these transformations are also of three types; namely:

(1) *Motor-dynamos*, or those in which a motor operates a dynamo which is directly coupled to it.

(2) *Dynamotors*, or those in which the motor and dynamo windings are associated upon the same core and pass through the same field.

(3) *Rotary transformers* in which a common winding is connected to collector-rings for alternating currents and also to a commutator and brushes for continuous currents.

A secondary generator of the first class may be called a *continuous-current secondary-generator*, while for the second and third types it might be called an *alternating-current secondary-generator*.

Continuous-current secondary-generators, are frequently used either to charge storage batteries, or to raise the pressure on a feeder. When a system of low-tension mains is being fed from a central station, at a steady pressure, it may happen that the voltage is low on some outlying district supplied by a special feeder. In order to increase the voltage on this district, without increasing the pressure on the remainder of the system, a generator of suitable type is inserted in the circuit of the feeder supplying the district, and is operated so as to add its E. M. F. to that produced by the central-station dynamos. Such a generator, since it raises the pressure, is sometimes called a *booster*. Fig. 415, shows a *central-station booster* for three-wire service. M_1 and M_2, are two 75-K. W., 240-volt compound-wound motors, one or both of which may be driven by current taken from the bus-bars of the station through suitable switches. B and B, are two *generators*. The armatures of these machines are connected directly in the circuit of the feeder, whose pressure is to be raised; B_1, being in the negative conductor of the feeder, and B_2, in the positive conductor. The current is supplied through the massive copper cables to the heavy brush holders supported in a massive rocker arm. When the armatures are at rest, the current passes through each, without encountering any E. M. F., and only the mere resistance of the armature winding, whereby the drop of pressure in the feeder is increased instead of being diminished. As soon as the armature is driven up to speed, by one or both motors, it can be caused to produce an E.M.F. as high as 60 volts, by adjusting the excitation of the separately-excited field magnets m, m. By this means the increase of pressure on the feeder can be made anything

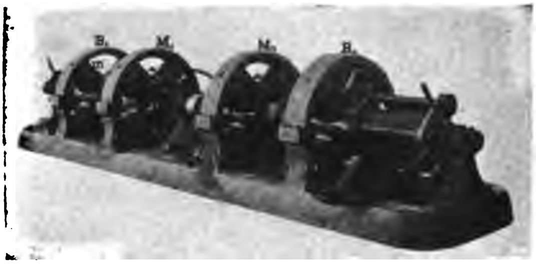


Fig. 415—"General Electric" Booster Set.

from 0 to 60 volts, the maximum current supplied through the armatures being 1,200 amperes each.

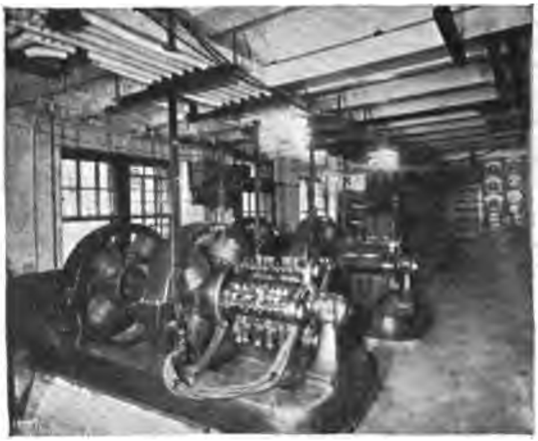


Fig. 416—A Pair of "General Electric" Booster Sets.

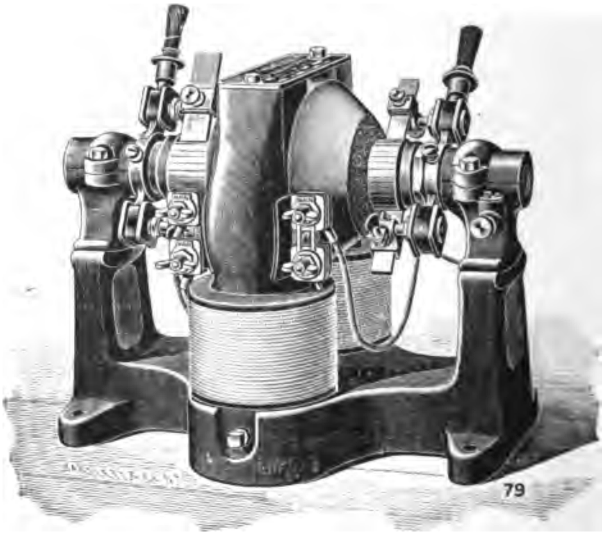


Fig. 417—Crocker-Wheeler Continuous-Current Dynamotor.

Fig. 416, shows a pair of similar motor-generators in separate sets in the central station of the Edison Illuminating

Company at Boston. The positive machine is here driven by one motor, and the negative machine by a separate motor. P P P P, shows the path of the positive-feeder, leading through the positive armature, and N N, the corresponding path of the negative-feeder, leading through the negative armature.

Fig. 417, shows a Crocker-Wheeler Company's continuous-current dynamotor of the step-up type, intended for being operated by an incandescent-lighting circuit and delivering 2,500 volts pressure for insulation testing purposes. The right-hand side of the armature is the motor side, receiving the incandescent-lighting current, at a pressure of say 230 volts, and on the left-hand side are the commutator and brushes, for supplying 2,500 volts. This machine has 2 H.P. capacity, and, consequently, is capable of receiving about 6 amperes and delivering about 6-10 ampere.

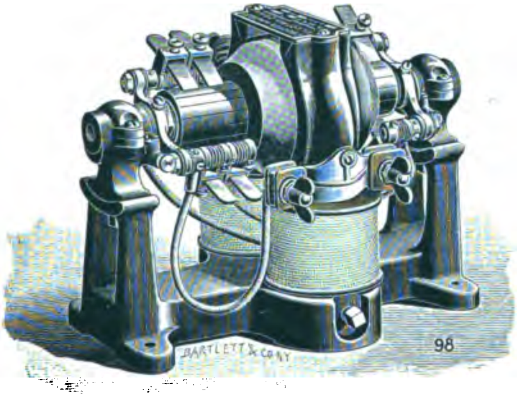


Fig. 418—Crocker-Wheeler Continuous-Current 1-2-H.P. Dynamotor.

The Crocker-Wheeler dynamotors run counter-clockwise when looked at from the motor ends.

Fig. 418, shows a Crocker-Wheeler continuous-current dynamotor, for reducing from incandescent-lighting pressure to electroplating pressure, while Fig. 419, shows a Crocker-Wheeler continuous-current dynamotor for increasing from voltaic battery pressure to 150 volts pressure. The sizes and weights of these machines are given in Fig. 420.

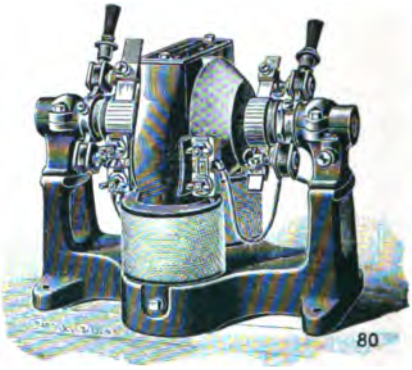
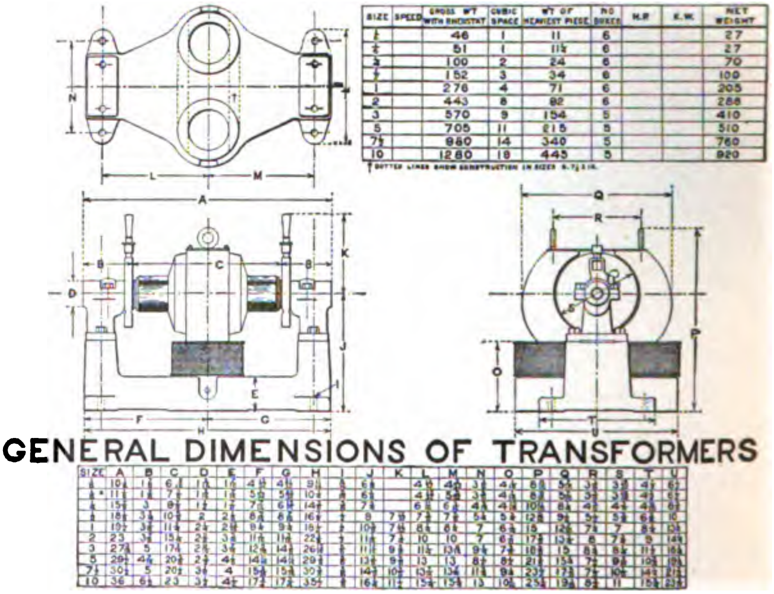


Fig. 419—Crocker Wheeler 1-6-H.P. Continuous-Current Dynamotor.



SIZE	SPEED	GROSS WT WITH RHEOSTAT	CUBIC SPACE	WT OF HEAVIEST PIECE	NO BOXES	H.P.	K.W.	NET WEIGHT
1/6		46	1	11	6			27
1/4		51	1	11½	6			27
1/2		100	2	24	6			70
3/4		152	3	34	6			100
1		276	4	71	6			205
2		443	8	82	6			288
3		570	9	154	5			410
5		705	11	215	5			510
7½		980	14	340	5			760
10		1280	18	445	5			920

† DOTTED LINES SHOW CONSTRUCTION IN SIZES 5, 7½ & 10.

Fig. 420—Diagram of Crocker-Wheeler Dynamotors from 1-6 to 10-H.P.

A Crocker-Wheeler Electric Company's 2 1-2 K. W. dynamotor for transforming from continuous to alternating currents is shown in Fig. 421. This machine receives a continuous current at terminals T, T, one of these only being visible, supplying the commutator C, and shunt field magnet windings M. Brushes b, b, resting on collector rings r, r, carry off the secondary alternating current of low frequency at about 40 volts pressure. The machine is designed for electric heating.

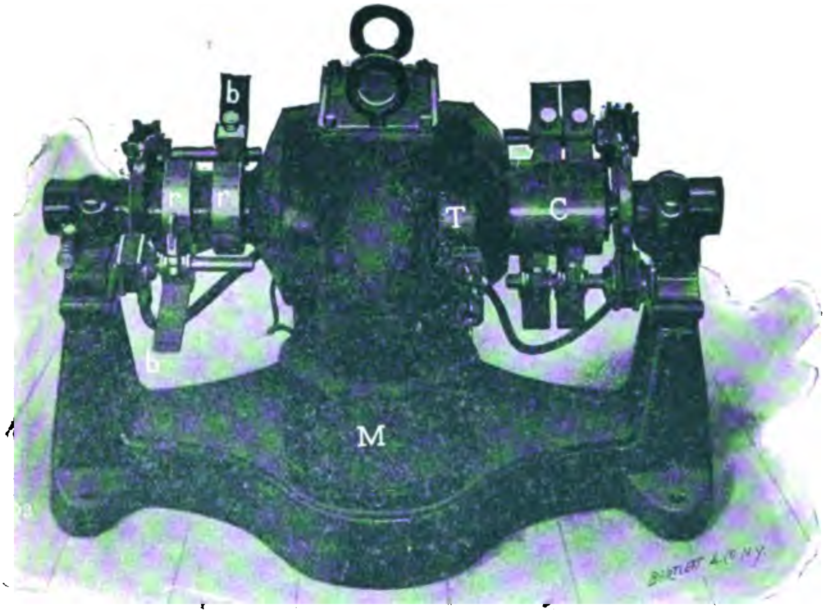


Fig. 421—Crocker-Wheeler Size 5 Dynamotor.

Fig. 422, shows a 1-6 H. P. Crocker-Wheeler Electric Company's continuous-current dynamotor for charging storage batteries. It receives current from incandescent lighting mains at 110 volt pressure at terminals T, T, through the switch *s*, to the commutator c. The secondary winding on the armature is connected to the commutator C, and supplies the brushes B,B, connected to one of the secondary terminals through the automatic switch S. As the secondary winding comprises a comparatively small number of heavy turns of wire, the secondary pressure is small, with a correspondingly large current. For this reason the secondary commutator surface C is considerably larger than the primary commutator surface c, although nearly the same amount of electric energy passes through each. The more distant field magnet is hinged at the base, so as to be capable of a limited range of movement to and from the armature under magnetic attraction. When the primary switch *s* is closed, thereby exciting the field magnets, these tend to hug the armature and so close the charging circuit of the secondary winding through the switch S. As soon as the switch *s* is opened, or the primary current is accidentally cut off, the field magnets lose their excitation, the distant

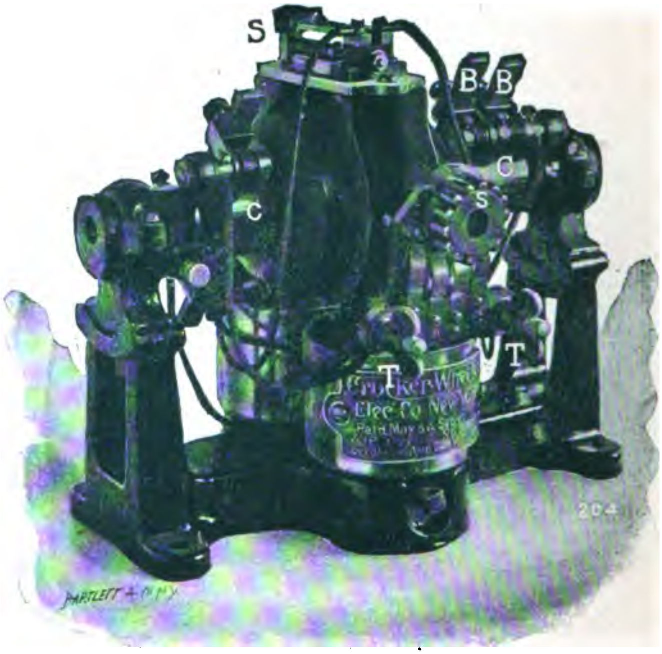


Fig. 422—Crocker-Wheeler 1-6-H.P. Continuous-Current Dynamotor.

pole-piece moves back and breaks the storage battery circuit at S. This prevents the storage cells from accidentally discharging through the secondary generator.

Fig. 423, shows a 1 H. P. Crocker-Wheeler motor-dynamo for telegraph work. The left-hand side P, of the machine is the primary side, receiving current from incandescent-lighting mains. The right-hand side S, is the secondary side, supplying continuous currents for telegraph circuits. The reason for employing two field magnets, i. e., motor-dynamo instead of a dynamotor, is that the secondary pressure can be regulated by regulating the secondary field current, without affecting the speed or primary field.

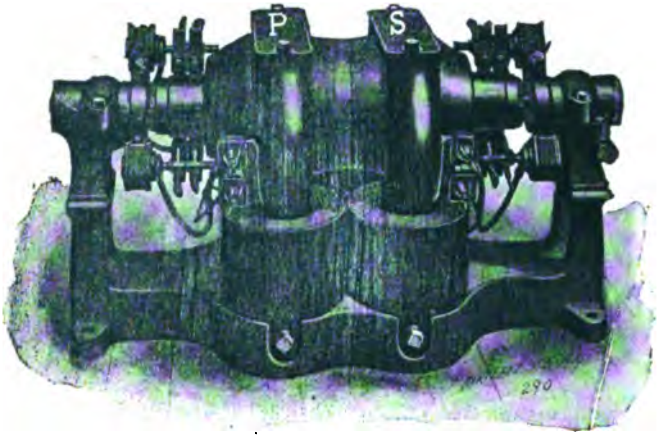


Fig. 423—Crocker-Wheeler 1-H.P. Motor-Dynamo for Telegraph Work.

Fig. 424, shows a Crocker-Wheeler Electric Company's 80 K. W. " Booster " or motor-dynamo for electric light feeders. One machine, A, is operated as a motor from the station bus-bars, and drives the other, B, as a generator. The armature of B is in circuit with a feeder or feeders, and the E. M. F. generated in B is added to these feeders, thereby raising the pressure they deliver. The secondary pressure so added is controlled by the field excitation of B. The entire machine weighs 11.5 tons, and the " booster " capacity is 80 K. W. at the full secondary voltage.

Fig. 425, shows a battery of Crocker-Wheeler Electric Company's dynamotors employed in a Central Telephone Exchange. A and B are ringers, i. e., 1 H. P. continuous-alternating dynamotors, operated at incandescent lighting pressure and delivering alternating-currents of pressure and frequency suitable for working call bells. C and D are 1-6 H. P. continuous-current dynamotors, also operated at incandescent-lighting pressure, and supplying a low-pressure continuous-current used in restoring the annunciator drops automatically on the insertion of connecting plugs when the calling subscriber is answered at the telephone switchboard. A and C are working machines, B and D being kept in reserve.

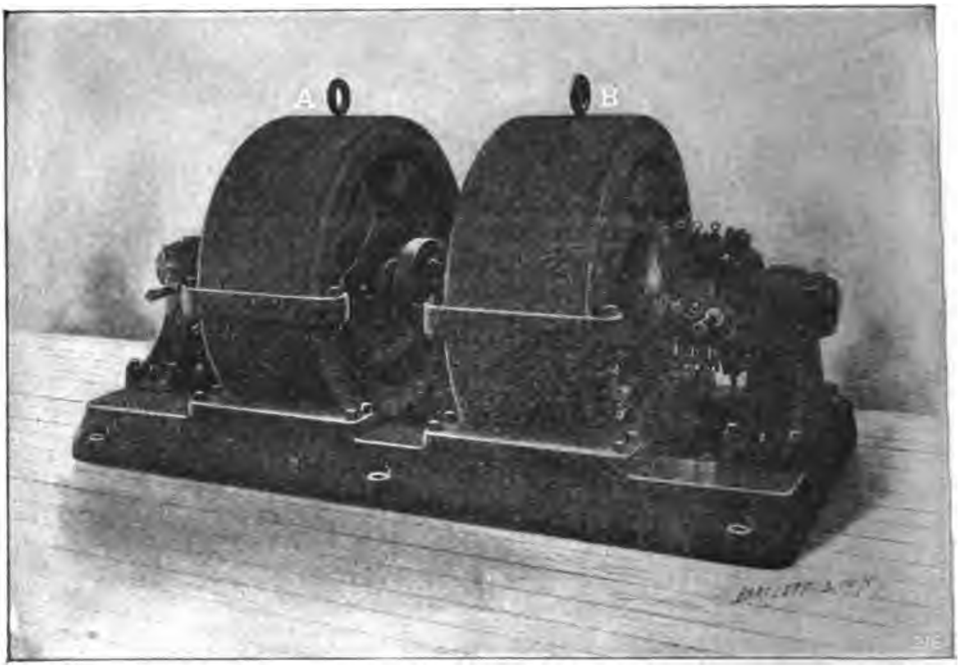


Fig. 424—Crocker-Wheeler Size 90 C.W. Booster.

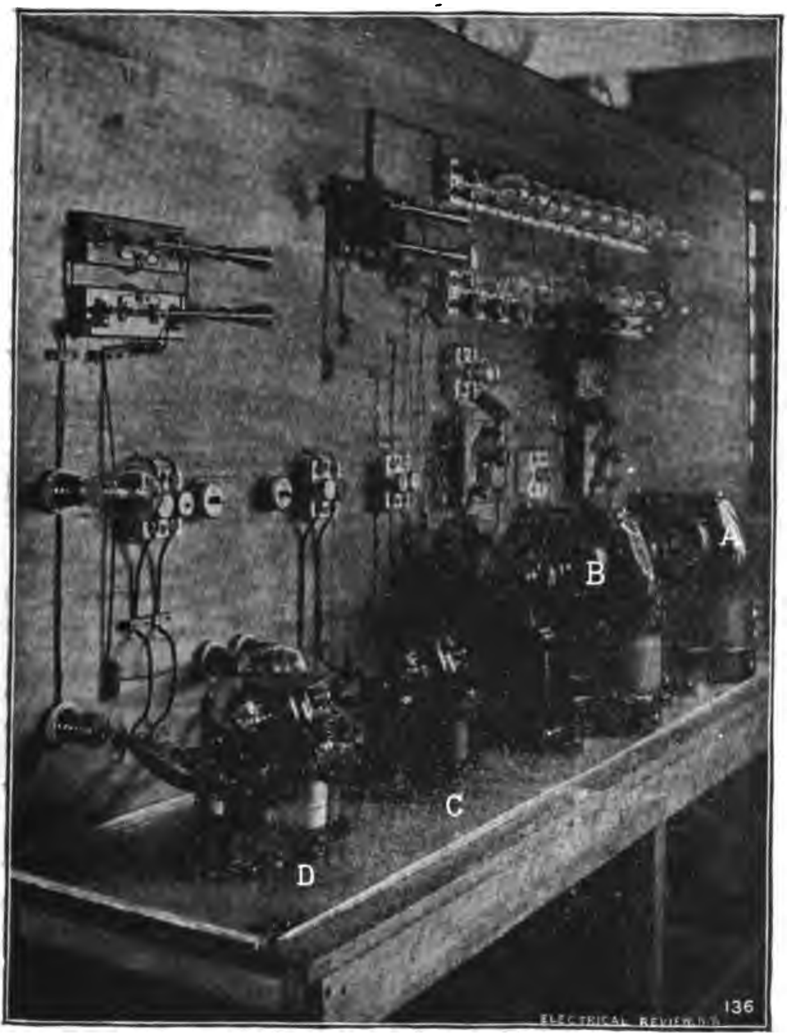


Fig. 425—Crocker-Wheeler Telephone Central Battery of Dynamotors.

Fig. 426, shows a group of four General Electric Company's diphase rotary convertors at Niagara Falls for supplying continuous currents. These machines have each a capacity of 600 K. W. and have 16 poles, running at 188 revolutions per minute. Diphase alternating currents, at 2,000 volts pressure are received in the building and transformed to alternating currents of 115 volts pressure, by two sets of 200 K. W. alternating-currents transformers shown, one set for each phase. The alternating-currents from the secondary circuits, at 115 volts pressure, are then supplied to the alternating-current side of the rotary transformers which are thereby operated as diphase motors. When their armatures are in operation, the commutators they carry enable the brushes to take off continuous currents from the same windings. The machines in the foreground of the figure are blowers for cooling the stationary transformers by air blast.

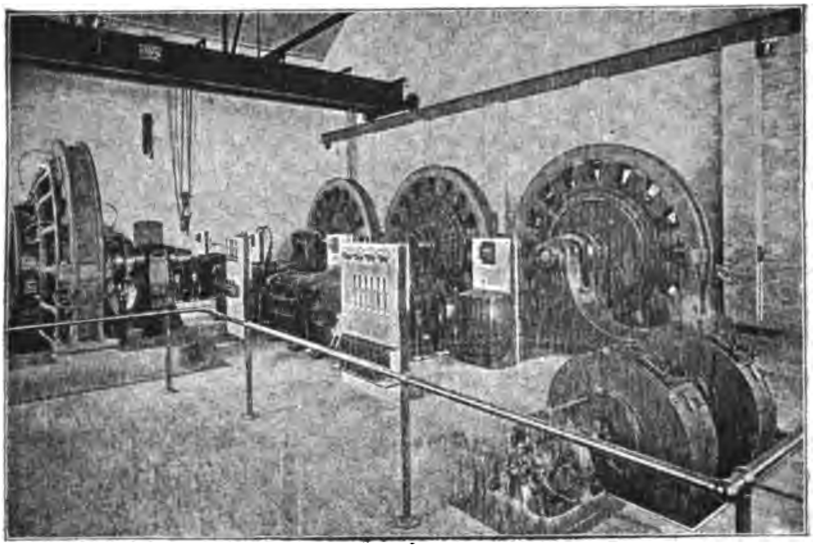


Fig. 426—General Electric Diphase Rotary Converters at Niagara Falls.

Fig. 427, shows the alternating-current side of another form of General-Electric Company's rotary converter with its collector-rings, while Fig. 428, shows the continuous-current side, with its commutator and brushes, the handles being employed to raise or depress the brushes together and also to shift their position together.

This machine occupies a floor space 10′ x 13′ 6″ and is 11′ 6″ high. It weighs, approximately, 80,000 pounds. It receives diphase alternating currents, at about 110 volts pressure, and delivers continuous currents at, approximately, 160 volts pressure. The armature is so constructed that the air passing through it is blown on to the commutator, thereby cooling the same. The temperature elevation of these machines is about 36° C on full load. This machine is self-excited and is self-starting. Its field is shunt-wound and receives current from the continuous-current side. The armature consists essentially of a continuous-current winding, tapped at suitable points for connection to collector-rings, so that the current enters the winding on one side as an alternating current and leaves on the other as a continuous current.

Fig. 429, shows a General Electric Company's three-phase rotary converter for supplying a railroad circuit from a triphase circuit. This machine has a capacity of 400 K. W., has 8 poles and makes 500 revolutions per minute. It is, therefore, operated on a circuit of 33 cycles per second. It occupies a floor space of 9′ x 9′ 3″ and has a height of 8′ 6,″ its weight being about 38,000 pounds. It receives triphase currents on the alternating-current side, at 330 volts pressure, and delivers continuous currents at its commutator and brushes, at 550 volts pressure. It is shunt-wound, self-excited and self-starting, when supplied from the alternating-current circuit.

Fig. 430, shows a General Electric Company's two-phase or quarter-phase rotary converter at the Niagara Falls power house. This machine has 400 K. W. capacity, with six poles; and makes 500 revolutions per minute, repre-

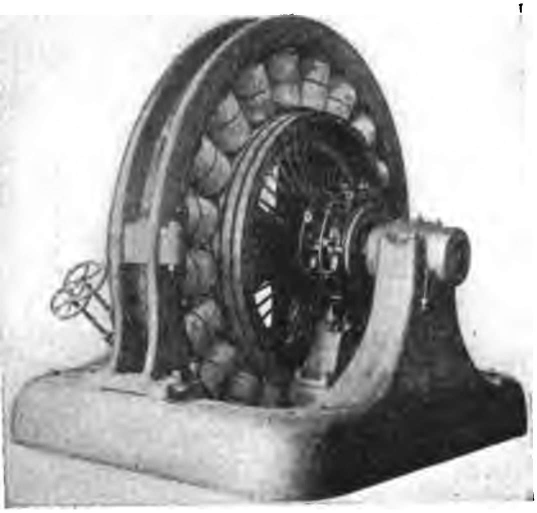


Fig 427—General Electric Rotary Transformer.

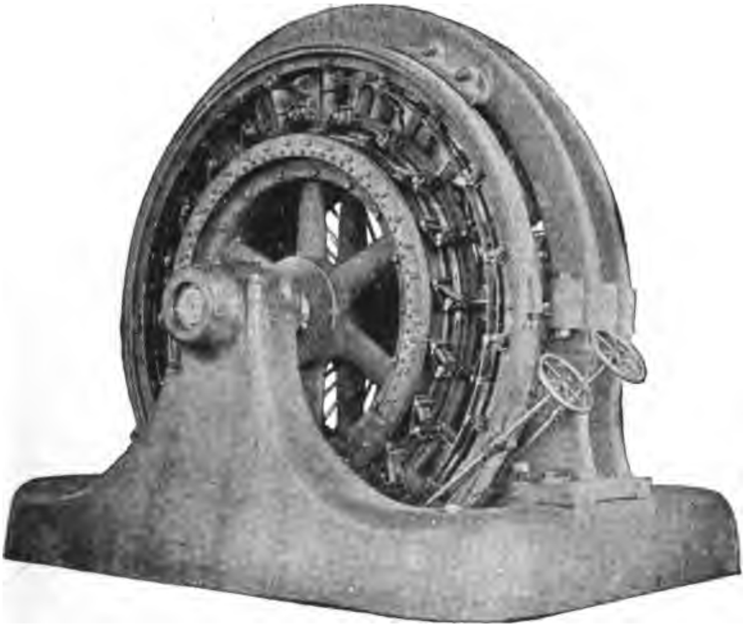


Fig. 428—General Electric Rotary Transformer Showing Continuous-Current Side.

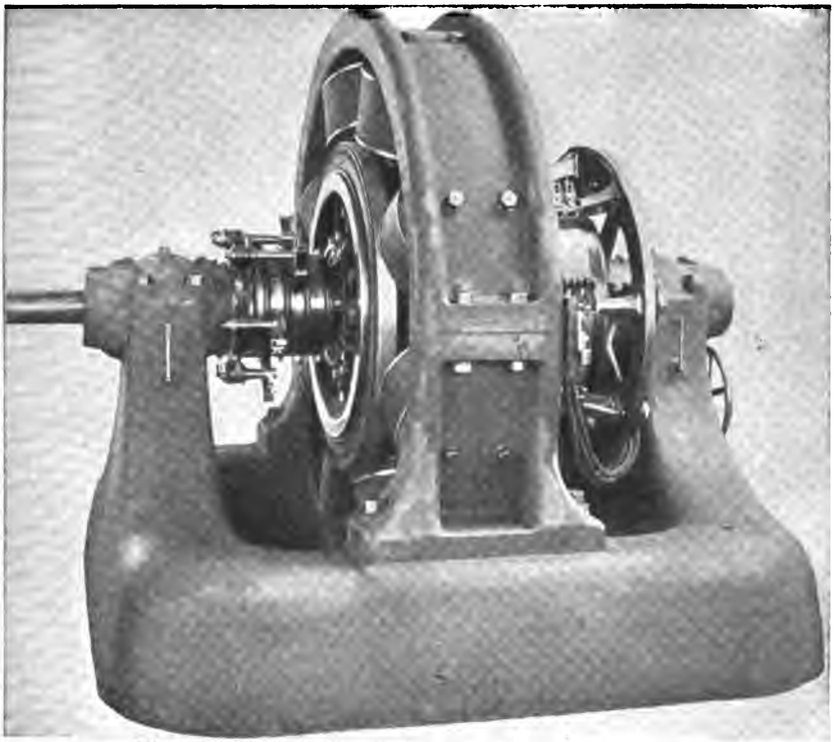


Fig. 429—General Electric Triphase Rotary Transformer.

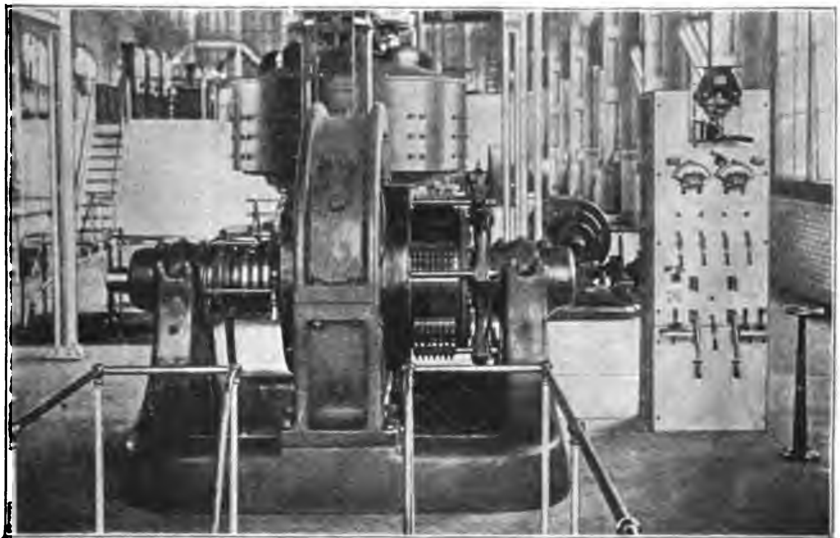


Fig. 430—General Electric Diphase Rotary Transformer at Niagara Falls.

senting a frequency of 25 cycles per second. It receives diphase currents, at its alternating-current side and delivers continuous currents, from carbon brushes at 575 volts pressure. It is employed to excite the fields of the large Westinghouse turbine diphase generators of 5,000 H. P.

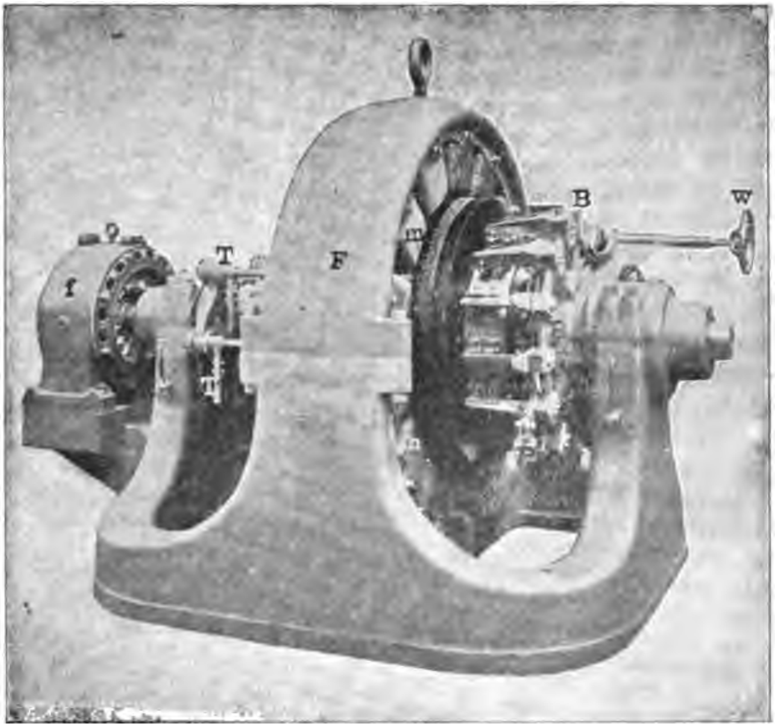


Fig. 431—Westinghouse 250 K. W. Two-Phase Rotary Transformer.

Fig. 431 and 432, shows a Westinghouse Electric Company's two-phase rotary transformer of 250 K. W. capacity. This machine transforms diphase alternating currents received at four collector rings and terminals T T, into continuous currents delivered at the brushes B B resting on the commutator ; w is the brushholder-circle adjuster ; m m, the field magnets excited by currents delivered from the brushes. In order to start the machine by diphase currents from rest in the unexcited condition, a small starting diphase induction motor f is placed on the same shaft.

Fig. 433, shows the armature of this machine A is the main armature provided with collector rings r, r, on one side and a commutator c, on the other. a is the armature of the small starting induction motor.

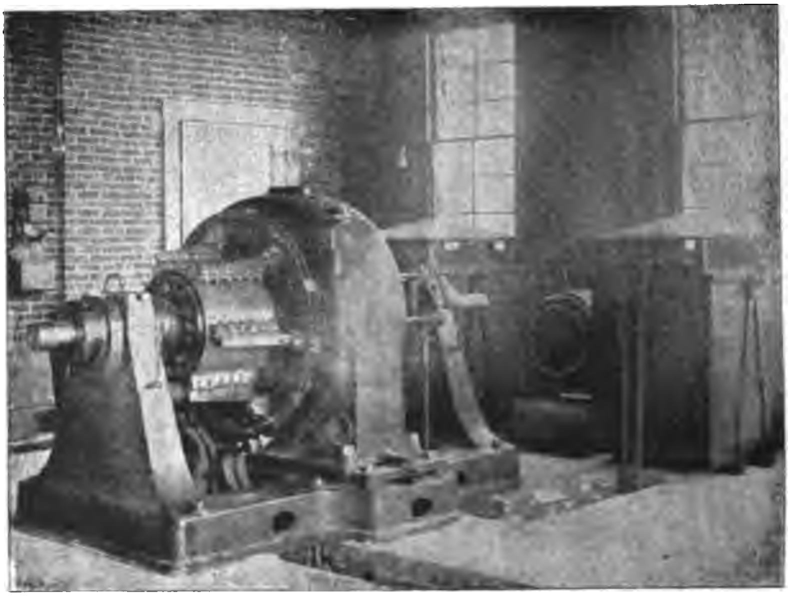


Fig. 434—Westinghouse 175-K. W. Two-Phase Induction Rotary Transformer.

Fig. 434, shows a Westinghouse two-phase 175-K.W. induction rotary transformer. The diphase alternating currents are admitted to the armature winding at the distant end through collector rings. The commutator at the near end is connected with the winding, and delivers a continuous current through carbon brushes to a continuous-current circuit at a pressure of from 125 to 165 volts. This pressure is controlled by varying the voltage of alternating current supplied, but may be also adjusted by varying the

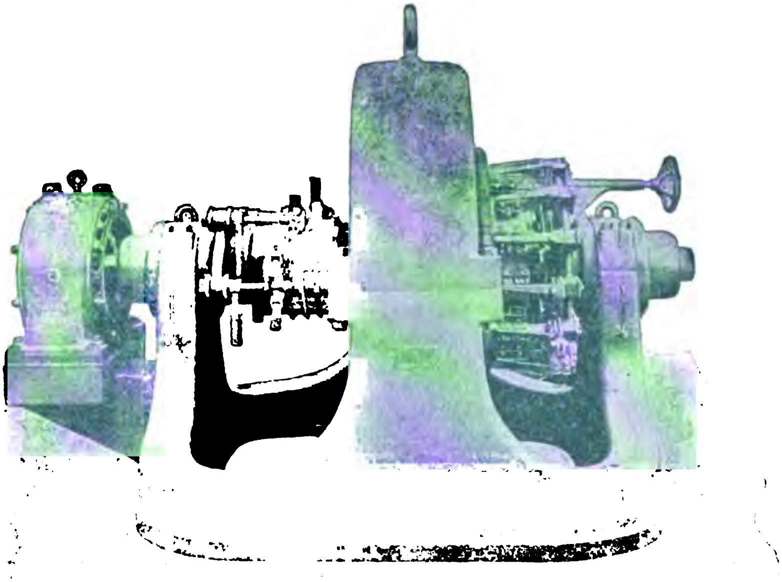


Fig. 432—Westinghouse Two-Phase Rotary Transformer.

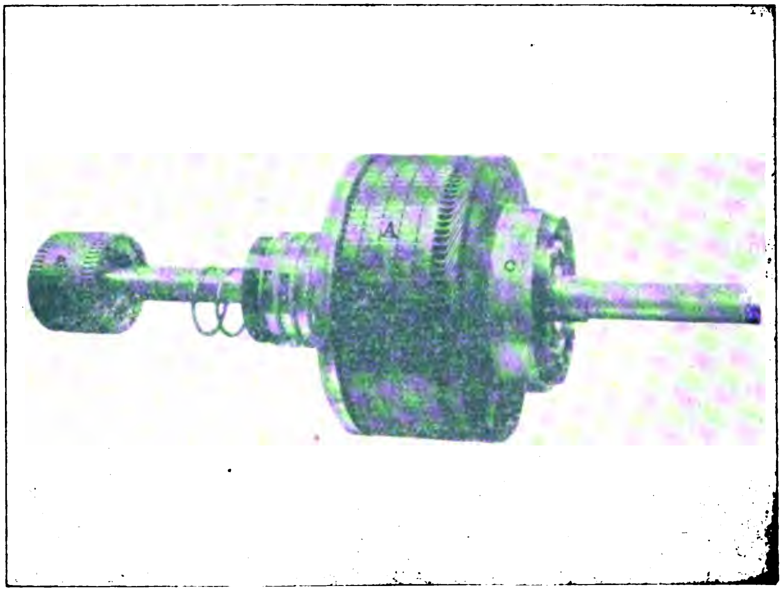


Fig. 433—Westinghouse 250 K. W. Two-Phase Rotary Transformer Armature.

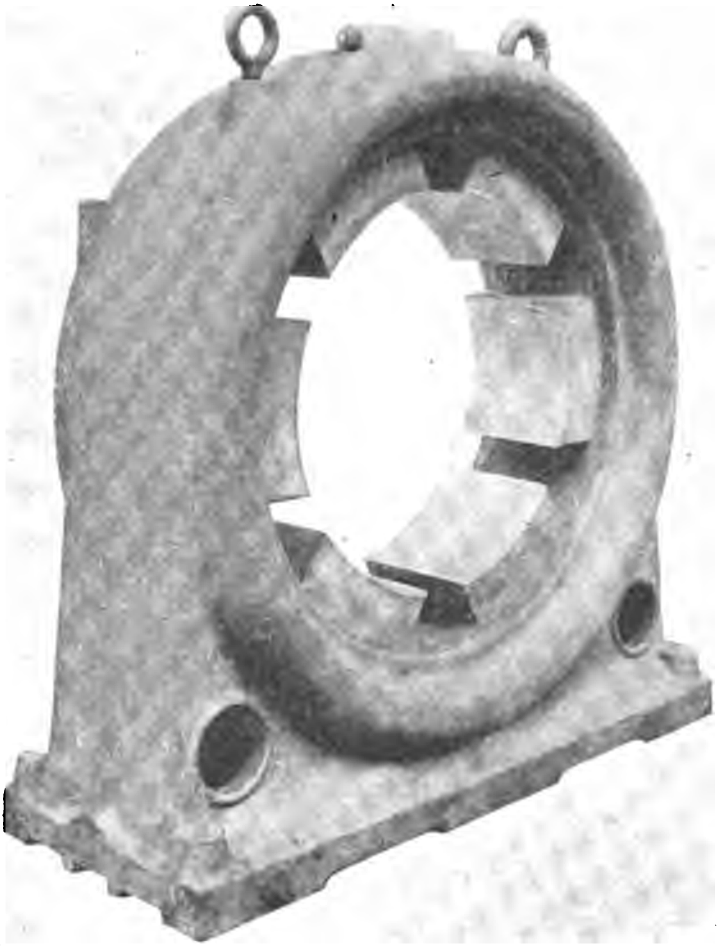


Fig. 435—Field Frame of Westinghouse Induction Rotary Transformer.

lead of the brushes on the commutator, with the aid of the handle H. The machine is supplied through the two transformers shown in the distant part of the room, one transformer being connected in each of the two diphase primary circuits. This machine is self-starting and runs at synchronous speed. It is capable, however, of running at speeds below synchronism as an induction machine. The field frame of the machine is shown in Fig. 435. It has six poles, but these have no field winding. The excitation is supplied entirely from the armature or rotor, and the diphase currents circulating in it. The machine starts as an induction motor but runs at synchronism in magnetic relation to the polar projections of the stator. Should any disturbance affect the system, such as an overload or short circuit, the machine will not be appreciably affected, for even if it breaks synchronism it will continue to run as an induction motor until synchronism has been regained.

THE END.

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